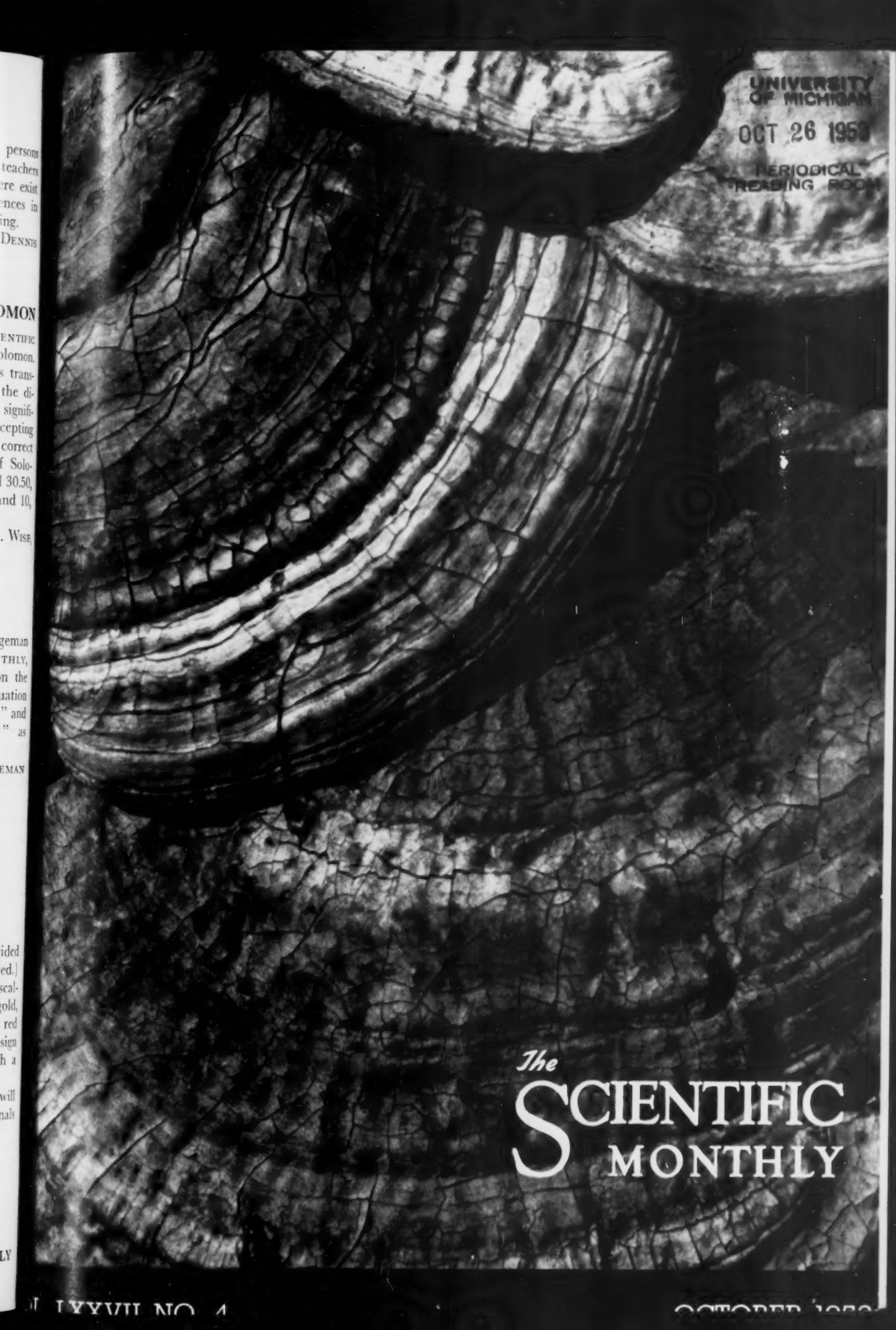

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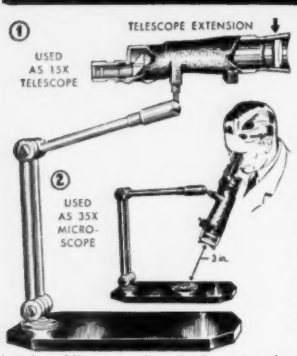

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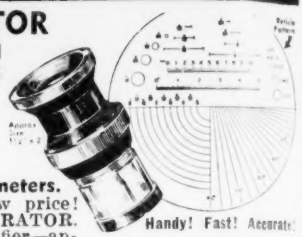

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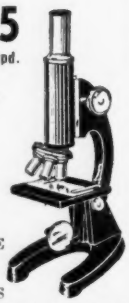

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THE SCIENTIFIC MONTHLY

OCTOBER 1953

The Age of the Universe

D. TER HAAR

Dr. Dirk ter Haar received his education at Leyden University where he studied under the late H. A. Kramers. After a year and a half in Niels Bohr's Institute for Theoretical Physics in Copenhagen, he was a Visiting Professor of Physics at Purdue University, from 1947 to 1950. Since 1950 he has been Lecturer in Theoretical Physics, United College of the University of St. Andrews, Scotland. He is a Fellow of the Royal Society of Edinburgh and of the Royal Astronomical Society. He is currently writing a book giving a critical and historical survey of existing theories on the origin of the solar system.

WHEN we contemplate the universe, the question comes into mind whether the present situation has existed in essentially the same form since time immemorial, or whether at some time in the very remote past conditions were completely different. Quite clearly, this question can never be finally settled, since we can only draw conclusions about the past by studying the present and by drawing inferences from it. Since these inferences will be based on the laws of nature as we believe them to be correct at this moment, it follows that any change in the accepted laws of nature will involve a change in the conclusions which we draw regarding the past. We thus see that none of the results that will be discussed in the present paper can be treated as presenting us with a final answer to some of our questions, but rather as giving a possible clue to such an answer. It is, therefore, all the more surprising—and perhaps satisfying—that a large number of independent investigations all seem to lead to the same conclusion, namely, that about three to five billion years ago some fundamental process—perhaps best described as a kind of "catastrophe"—happened, but that during the last one to three billion years the universe has existed in essentially its present condition. This period of the last few billion years we shall call the *present epoch* and its length we shall call the *age of the universe.*

Before we discuss in detail how one can arrive at an estimate of the age of the universe, it is necessary to remind ourselves what we really mean when we use the phrase "age of the universe." The best way to see the meaning of this phrase is perhaps to quote Chandrasekhar.[1] "An important phase of modern astronomical research is concerned with the time scale of the universe, i.e., with the specification of a natural unit of time in which it would be most convenient to describe the changing aspects of the astronomical universe. Stated in this manner, it is apparent that the solution to the problem of the time scale will not permit us (not at any rate in the first instance) either to 'date' the present epoch in a 'fundamental' calendar or to forecast with definiteness the 'end.' What it would allow us, however, is to specify an interval of time in which various aspects of the astronomical universe may be expected to change appreciably. Conversely, the

solution to the problem of the time scale will ultimately depend on the study of a variety of different aspects of the universe and the establishment in each case of a time interval during which the aspect studied might change to an appreciable extent. And if such studies would lead us in most instances to time intervals which are of the same order of magnitude, it would not be unreasonable to attribute to a unit of time of this order of magnitude a fundamental significance. It would appear that this is the only manner in which a rational approach to the problem of the time scale can be made. However, in formulating the problem in this manner it is evident that a certain element of arbitrariness has been introduced into the discussion. But this is unavoidable and inherent in a problem in which the emphasis is on an order of magnitude and not on an absolute measure."

We shall discuss, successively, nine subjects, all of which can give us an indication towards the most likely value of the age of the universe following from data at present available. These subjects are, in order of increasing distance from the earth: (i) the age of the earth, (ii) the age of the moon, (iii) the age of the meteorites, (iv) distribution of stars among spectral classes, (v) distribution in kinetic energy of stars, (vi) distribution in separation of binaries, (vii) dynamics of star clusters, (viii) dynamics of clusters of galaxies, and (ix) the expanding universe. At the end of the discussion we shall briefly summarize the results.

The Age of the Earth

In 1926, during his term as Chairman of the Division of Physical Sciences of the National Research Council of the National Academy of Sciences in Washington, D. C., J. S. Ames appointed a committee to prepare a series of bulletins on the physics of the earth. One of these bulletins, published in 1931,[2] deals with the age of the earth. The summary of the principal results of this volume by Knopf begins with the following paragraph: "At the beginning of the present century the problem of the age of the earth was envisaged as requiring the reconciliation of three independent estimates, all of the same order of magnitude. These estimates were G. H. Darwin's, of 57 million years, based on the separation of the moon from the Earth; Lord Kelvin's, of 20–40 millions, based on the secular cooling of the globe; and Joly's, of 80–90 millions, based on the rate of accumulation of sodium in the world-ocean. To these should be added Helmholtz's estimate of 22 million years, based on the source of the sun's heat and its probable duration."

At that time it appeared that the age of the earth was between 10 and 100 million years and that it might be possible by refining the methods used to narrow down the margin of uncertainty. However the methods on which the above estimates were based were found to be incorrect, as soon as the importance and implications of radioactive processes were realized. Taking these implications into account, one finds that one must adjust the estimate of the age of the earth upward by a factor as large as 30 to 100. As we shall see, radioactive dating presents us with a far more reliable method for determining the earth's age than any of the older methods.

We realize that during the present century the estimate of the earth's age has increased considerably, and it is perhaps of interest to give a brief sketch of the various estimates of this age in the past. Probably the most remarkable estimate is the one by the ancient Hindus who calculated that the earth was created 1,972,949,054 years ago. It is amazing that this estimate is of the same order of magnitude as the most reliable estimate available at the present.

Western civilization, however, did not have such a generous idea of the magnitude of the earth's past until very recently. Up to the eighteenth century, the earth's age was estimated by taking as literal and scientific truth the Mosaic traditions as laid down in the Pentateuch, so that in the early seventeenth century Archbishop Ussher could state that the world was created in the year 4004 B.C. Scientists expressing doubts as to the scientific reliability of this estimate were considered heretics.

In 1715, the well-known astronomer Halley suggested in a communication to the Royal Society that it might be possible to determine the age of the earth by measuring the salinity or salt content of the oceans. Owing to the influence of the established church, Halley was thinking in terms of thousands of years as the possible age of the earth and expressed regret that the Romans or Greeks had not "delivered down to us the degree of the saltness of the sea, as it was about 2000 years ago: for then it cannot be doubted but that the difference between what is now found and what was then would become very sensible." He expressed, however, the opinion that "the world may be found much older than many have hitherto imagined."

Later in the eighteenth century James Hutton, often called the father of modern geology, was the first to grasp clearly the magnitude of geological times. In considering the geological data then available, he came to the conclusion that it was impossible to find a "vestige of a beginning." Once the

idea won ground that the geological time scale was extremely large, geologists began to expand their periods. Darwin, for instance, estimated in 1859 the period of the formation of certain geological structures in southern England to be about 300 million years. At present we know that it is more likely to be about 60 million years, but all the same, Jukes, commenting on Darwin's estimate, thought that this period might just as likely have been 30 billion years! By the end of the nineteenth century, however, various methods for evaluating the age of the earth were developed. It was estimated to be between 10 and 100 million years of age.

We now discuss briefly a few methods by which one can arrive at an estimate of the earth's age, and give the results obtained by these methods. We refer to the account given by Holmes,[3] or the recent discussion by Sir Harold Jeffreys,[4] for a more detailed consideration. The methods that we will discuss are: (i) estimating the period necessary for the earth to cool to its present temperature; (ii) estimating the period necessary to produce the present salinity of the oceans; (iii) estimating the period necessary to produce the sedimentary rocks; and iv) estimating the age of igneous rocks from their lead content.

Cooling of the earth's crust. In 1862, Lord Kelvin considered the problem of estimating the time necessary for the cooling of the earth's crust from its original molten state to its present temperature. He used the fact that the temperature is increasing when we penetrate downward, and from the data available at that time he estimated the age of the earth to be between 20 and 400 million years, an estimate that he revised in 1897 to an age lying between 20 and 40 million years. His estimate was questioned by Perry, who, on the basis of different values for the thermal conductivity of the interior of the earth, arrived at a value of the order of 4 billion years.

Clearly, it was impossible for Kelvin to take radioactivity into account, and this means that his estimate has to be revised. The presence of radioactive materials in the earth's crust means that there is a source of energy that will, of course, retard the cooling process. From the known abundance of these radioactive sources one can arrive at a new estimate of the rate of cooling. In this way Holmes[3] arrives tentatively at an estimate for the age of the earth of between 2 and 4 billion years.

Salinity of the oceans. In 1898, Joly used Halley's suggestion to determine the age of the oceans. Measuring the total amount of sodium carried annually to the seas by the rivers and also the total amount that is present in the oceans, he arrived at an age of about 80 to 90 million years.

In 1942 and 1943, Conway re-examined this question in detail and showed that most of the sodium carried by the rivers is "second hand" sodium, that is, sodium that had previously been deposited by the sea, and that only a fraction of the sodium in the rivers is "new." This fact alone would raise the age of estimate by a factor between 2 and 3, leading to an age of about 150 to 250 million years. As Holmes has pointed out, however, it is very likely that in the past a lesser area was exposed to denudation, so that the rate at which sodium is carried to the seas has increased with time. It hardly needs emphasizing that such a variable timekeeper as the sodium content of the oceans cannot lead to any definite estimate of the age of the earth. Tentatively, Holmes estimates that the slower rate in the past should lead to an increase of the age by a factor between 8 and 27, so that we are finally led to an age of between one and seven billion years.

The formation of sedimentary rocks. The igneous rocks, which are at present exposed so that they can produce sediments, annually produce about one-fifth of a cubic mile of sediments. The total volume of sediments at the present time is estimated to be about 70 million cubic miles. If the rate of sedimentation had been constant, this would mean that it had proceeded for about 350 million years. However, it is most probable that this figure should be multiplied by a factor of the order 10, for the same reasons as given in the previous paragraph.

Radioactive methods. The main difficulty with the three preceding methods is that none of them deals with a process of which the rate has been constant in the past. Clearly, a method based on such a constant process would be greatly superior to the other ones. Fortunately, we possess such a process in radioactive decay, as there is reasonably reliable evidence[5] that the rate at which radioactive nuclei decay has not changed appreciably over at least the last billion years.

It is very easy to obtain an upper limit for the age of the earth, either from the fact that uranium and thorium are still present in rocks, or from the present isotopic-abundance ratio of uranium. H. N. Russell pointed out that since the half-lives of U^{235}, U^{238}, and Th^{232} are, respectively, 0.7, 4.5, and 14 billion years, the mere fact that they are still present on the earth in appreciable quantities indicates that the earth cannot be older than about 10 billion years.

At present, the ratio of U^{238} to U^{235} is about 139. Since U^{235} is decaying nearly seven times as fast

as U^{238}, we can calculate at what moment in the past the two isotopes would have been equally abundant. Since isotopes of odd atomic weight are always less abundant in nature than those of even atomic weight (apart from a few special cases), this period would give us another upper limit to the earth's age. This method, which we owe to Rutherford, leads to an upper limit of about 6 billion years.

More reliable methods for determining the age of the earth are based on the fact that U^{238}, U^{235}, and Th^{232} all decay to produce a stable lead isotope. The three end products are, respectively, Pb^{206}, Pb^{207}, and Pb^{208}, while the lighter lead isotope Pb^{204} probably existed in the primeval lead that was present from the beginning of the earth's history. The isotopic constitution of lead was modified by the production of "radiogenic" lead, that is, the decay products of uranium and thorium. At a certain moment in the development of the earth, minerals were formed, and, in general, minerals containing lead were separated from those containing uranium and thorium. One can now either consider the minerals containing uranium and thorium and from their lead content determine their ages and thus a lower limit for the earth's age, or one can consider the lead ores and, by a method to be described presently, arrive directly at an estimate of the age of the earth. The first method is the easier one, because the age of a mineral containing radiogenic lead and, say, thorium follows by a straightforward calculation from the abundances of Pb^{208}, and Th^{232} and the known rate of decay of thorium. The age of a great number of minerals has been determined in this way, and the results vary between 60 million and 2 billion years.

The second method that has been developed by Holmes[3,6] is probably the most reliable one for determining the age of the earth. The basic idea of this method is that the lead in lead ores will contain partly primeval lead and partly radiogenic lead, and that the proportion of radiogenic lead will be larger for the younger minerals. By a rather complicated analysis, it is possible to calculate the isotopic constitution of the primeval lead and hence

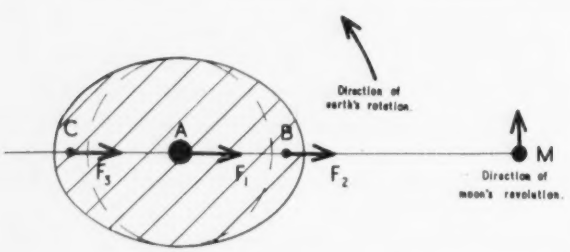

FIGURE 1.

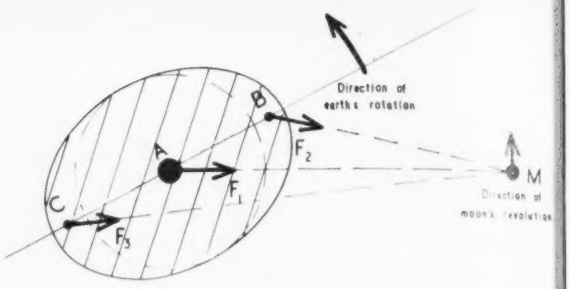

FIGURE 2.

the time before the lead ore was deposited. Adding to this period the age of the ore itself, one has obtained a value for the age of the earth. In this way, Holmes' method leads to an age that is just over 3 billion years.

The Age of the Moon

It is well known that the moon produces tides on the earth, but it is not always realized that these tides in turn influence the moon's orbit. Due to the fact that the earth is not perfectly elastic and that the oceans are not perfectly fluid (that is, the water in the oceans possesses viscosity), so-called *tidal friction*[7] will occur. It is only a small phenomenon but its effects are secular; that is, they accumulate over long periods and they may have been the cause of great changes in the orbit of the moon. Let us consider this in somewhat more detail. In Figure 1, we have pictured the situation that would arise if the oceans were perfect fluids. The tides would be exactly on the straight line connecting the center of the earth (A) with the moon (M). For the sake of simplicity, we have assumed that we may divide the earth's mass into three masses, situated at A, B, and C, corresponding respectively to the mass of the solid core of the earth and to the masses of the tides on the two sides of the earth. (It must be remembered that apart from the tide immediately under the moon, there is also a tide furthest away from the moon which is due to the fact that the moon is pulling harder at the mass at A than at the oceans at C.) In the case of Figure 1, the forces exerted by the moon on the masses at A, B, and C (indicated by F_1, F_2, and F_3) are all along AM and their resultant which is equal, but opposite in sign, to the force exerted by the earth on the moon, is also along AM. In this case, the moon would proceed along a circular orbit.

The situation is, however, different in the case depicted in Figure 2. If viscosity is present, the tides will lag behind and will only reach their highest point after they have passed under the moon. Since the earth is rotating faster than the moon is revolving around the earth, the situation will be as

pictured in Figure 2. Now the three forces F_1, F_2, and F_3 are no longer colinear, and since F_2 is larger than F_1 and also the angle *BMA* is larger than the angle *AMC*, there will be a resultant force on the moon that has a component perpendicular to *AM* in the direction of the moon's revolution. This force will tend to increase the moon's angular velocity and thus the distance *AM*.

From the analysis given in the preceding paragraph, we see that the moon must have been nearer to the earth in the past. Since the total angular momentum of the moon-earth system must remain constant, it follows that the earth's rotation must have slowed down, or, in other words, the days have lengthened. The effect is small, however, and Jeffreys estimates that the day has lengthened by about one second over the last 100,000 years. The effect also gives us a method for estimating the age of the earth-moon system, for which we can take, for instance, the period over which the moon receded from one-half of its present distance to its present distance.* The calculations are rather complicated and they lead to a value of between 2 and 4 billion years for the age of the moon and thus to a lower limit for the age of the universe.

The Age of Meteorites

We saw that the age of minerals could be determined successfully by examining their lead content. The same method has also been used, notably by Paneth and co-workers,[8] to determine the age of meteorites. Apart from this method, they also use the helium content of meteorites as an indicator of their age. The decay of uranium and thorium is by α-radioactivity and provided all α-particles are captured and no helium is produced by other processes, the helium content of a meteorite should be as reliable a guide to its age as is its lead content. By examining the helium content of several meteorites, Paneth arrives at ages ranging from 60 million to 7 billion years.

However, Bauer[9] has pointed out that there was a strong correlation between age and size of the meteorites or between helium content and size, in such a way that the smaller meteorites had the larger helium content and thus were the older ones on Paneth's scale. From this correlation, Bauer concluded that the large helium content in small meteorites might be due to a surface effect and not to radioactive decay. Indeed, cosmic rays are sufficiently efficient helium producers to account for practically all the helium in the small meteorites.

Re-examining the evidence, Bauer arrives at a common age of about 60 million years for the meteorites examined by Paneth. This would give us thus a lower limit for the age of the meteorites and also for the age of the universe. In view of the fact that many authors tend nowadays to the opinion that the breakup of a planet between Mars and Jupiter may have produced, among other things, the meteorites, the age determination of the meteorites may well be one of the more important clues to the past history of our solar system. If one accepts the idea that all meteorites have a common origin, one is tempted to suggest Holmes' method as a means to determine the age of the hypothetical planet that produced the meteorites.

Distribution of Stars Among Spectral Classes

In our quest for clues to the age of our universe we now leave the realm of our solar system and begin to consider the stars in general. We can either consider their physical properties and from the distribution of stars among the spectral classes arrive at an upper limit for the age of the universe, or we can consider their dynamical properties and from the distribution of their velocities try to derive data about the age of the universe. We shall discuss the second method later and for the present concentrate on the first method.

It is nowadays well established that the source of stellar energy is nuclear and, put in the simplest possible terms, is the conversion of four protons (or hydrogen nuclei) into one α-particle (or helium nucleus). If we know how large a fraction of a star is helium and how much energy the star radiates per unit time, we can calculate an upper limit for its age, if we assume that all the helium of the star was produced from hydrogen and that the energy output of the star has not changed during its life history. There are good reasons to believe that most stars, with perhaps a few exceptions, have the same chemical composition and that most stars contain (by weight) about 42 per cent helium and 51 per cent hydrogen. It then follows that the age of the various stars is directly proportional to their mass and inversely proportional to their energy output, or luminosity. In this way, Unsöld[10] has computed the maximum age of stars of different spectral classes. The sun, for instance, could at most be 40 billion years old, if we may use this yardstick. However, *O*, *B*, and *A* stars, the brightest stars in our galaxy,† which have slightly larger masses than the sun, but

* Fortunately, the age estimate is extremely insensitive to the initial distance *AM* and we would have obtained practically the same result if we had chosen the period over which the distance increased by a factor ten, or only by twenty per cent.

† The brighter stars in Orion are *O* and *B* stars, and Sirius is an *A* star.

far higher luminosities, could only have produced energy at the present rate for a period varying from a few million years for *O* stars to about one billion years for the brightest *A* stars. Clearly, we cannot use these data to determine the age of the universe, but rather we are led to the conclusion that stars are probably still being created, even at this moment. There are, indeed, many other indications that this is probably the true state of affairs.

Even though this first attempt at arriving at an estimate of the age of the universe by studying stellar evolution was not successful, nevertheless, as was shown by Russell,[11] it is possible to obtain an upper limit for the age of the universe by considering the evolution of a typical main sequence star, such as the sun. Let us therefore consider the evolution of the sun. At present the sun contains (by weight) 51 per cent hydrogen. Assuming that the carbon-nitrogen cycle[12] is in operation at present and has been in the past and will be in the future,* one can calculate both the luminosity and spectral class of the sun at any moment in the past and in the future, and the period that the sun would spend or has spent in each spectral class. It turns out that the sun, contrary to what one might expect, will start as a rather dim *K*-star and gradually brighten until it would finally become a hot, bright *B*-star. The reason is that when hydrogen is converted into helium the mean molecular weight will increase and therefore according to Bethe's theory of stellar energy production,[12] so will the central temperature. Since the energy production increases very strongly with increasing central temperature, the sun's luminosity will greatly increase. In order to get the heat flow in balance, the sun will expand; it will become slightly larger and much brighter and hotter.

From Russell's detailed considerations, it follows that the sun would spend the first few hundred billion years of its life as a *K*-star and, after that, about 30 billion years as a *G*-star, its present classification. In the near future (astronomically speaking), the sun would spend 5 billion years as an *F*-star, 3 to 4 billion years as an *A*-star and the last 500 million as a *B*-star. If the universe, or rather our galaxy, had existed for as long a period as 100 or 1000 billion years, we should expect to see stars of masses about equal to that of the sun distributed over the various spectral classes, roughly in proportion to the period spent in each spectral class. This would mean that in our galaxy there would be about six times as many *G*-stars as *F*-stars, and about seven times as many *A*-stars as *B*-stars of solar mass. Now, *A*-, *B*-, and *O*-stars are so much brighter than *F*-, *G*-, or *K*-stars, so that they can be seen at much greater distances. The distribution of stars observed on the earth over the spectral classes would therefore be different from the one that would be proportional to the period spent in each spectral class, since it is necessary to correct for this brightness effect. In fact, if one applies this correction, it turns out that the distribution of stars of solar mass observed on the earth would be such that there would be about three times as many *G*-stars as *K*-stars, and about ten times as many *A*- and *B*-stars as *G*-stars, if an equilibrium distribution had been reached. Actually, there are practically no stars of solar mass belonging to the spectral classes *A* and *B* and we can thus conclude that our galaxy is not old enough to have produced these stars. This leads us to an upper limit of the age of our galaxy of, say, 100 billion years.

As far as our sun is concerned, Ledoux[13] has recently arrived at an estimate of its age by assuming that the chemical composition of its outer envelope—which, as we saw a moment ago, contains about 40 per cent helium—is different from that of its core. It may be remarked here that the question whether or not mixing of various layers of a star occurs is still far from satisfactorily or finally settled. The difference between the chemical composition of the outer layer and of the core would be due to the transmutation of hydrogen into helium in the central parts. Considering a suitable model for the sun, Ledoux finds that whereas the envelope contains about 40 per cent helium, the core may contain as much as 70 per cent. Assuming that the outer parts show the original composition of the sun, Ledoux could estimate the age of the sun, for which he found a value of about 5 billion years.

As Bok[14] points out, stellar evolution as a possible indicator of the age of our universe becomes extremely unsatisfactory as soon as we try to take white dwarfs, which are probably relatively old stars, or giants and supergiants, which are probably relatively young, into account. The exploration of this large and important field has only just started.

Distribution in Kinetic Energy of Stars

The apparent approach to equipartition of kinetic energy for the stars in the neighborhood of the sun has been in the past one of the most powerful arguments in favor of the so-called long time-scale, that is, of adopting as the age of our universe a period of the order of a thousand billion years or even longer. This long time-scale was favored by the astronomers in the nineteen-twenties and early

* It is immaterial for the present discussion whether or not this assumption is well founded, as it very well may not be in the light of recent evidence.

nineteen-thirties. In 1929, for instance, Jeans[15] summarized the generally accepted point of view with the words "a good many lines of evidence converge in indicating ages of the order of from five to ten million million years for the main mass of the stars . . . and all the nebulae in the sky may be of the same age." This point of view was mainly based on Jeans' own researches on the ages of moving clusters and on the statistics of binary orbits, but work by Bok,[16] Ambarzumian,[17] and Kuiper[18] between 1934 and 1937 showed that Jeans' estimates were in need of a drastic revision; and, as we shall see presently, recent investigations of these subjects also lead to the short time-scale, that is, an age of the universe of a few billion years.

Let us return to the distribution of kinetic energy in our Milky Way. As early as 1911, Halm[19] pointed out that the average kinetic energy of stars in a given spectral class, with the exception of the *B*-stars, was roughly the same, independent of the spectral class—a result later verified for *M*, *A*, *F*, and *G* stars by Vyssotsky and Williams.[20] Since the relaxation time, that is, the time necessary to produce an equilibrium distribution leading to equipartition, in the neighborhood of the sun is of the order of 10,000 billion years, our galaxy should be at least a thousand billion years old.* However, the situation is not as simple as we have just pictured it.

Bok,[14] in his report to the Royal Astronomical Society in 1946, comes to the conclusion that there are too many deviations from total equipartition to enable us to arrive at an estimate of the age of the universe.† He concludes this section of his report with the following paragraph: "The whole problem of equipartition of kinetic energies and deviations from the mean reduces itself to a basic problem of galactic dynamics and of stellar evolution, one that we have hardly begun to recognize as a problem and for which the solution is not yet in sight. Formulated concisely, it reads: *How can we explain certain observed correlations between the physical properties of the stars (such as mass, period, spectrum) and their dynamical, or orbital characteristics in the galaxy?* (The italics are Bok's.) For the present we can only guess that from these correlations we may ultimately be able to draw important conclusions relative to the cosmic time-scale. We may, however, state with confidence that the equipartition argument can no longer be quoted in support of the long time-scale."

Recently, Gondolatsch[21] has considered this problem very carefully and although his results agree with Bok's conclusions, he feels that he is able to say that the distribution of kinetic energy among the various spectral classes points to an age of the universe of the order of a few billion years. However, this conclusion does not seem to be very vigorously founded.

Distribution in Separation of Binaries

For many purposes we may consider the gravitational field in our Milky Way to be a smoothed-out field of force, but sometimes it is necessary to take into account the fact that it really is produced by single stars. This means that we must consider the fluctuations in the gravitational field. As was shown by Chandrasekhar,[22] these fluctuations will ultimately cause a binary system to dissolve. The argument proceeds as follows: Since the two components of a binary star are slightly separated, the gravitational field due to a star passing in their neighborhood will differ for the two components. This difference in field strength will result in a difference in actual force acting on the two components and hence in an acceleration of one component relative to the other. This acceleration will be present only as long as the star is in the neighborhood of the binary system, but successive encounters will give rise to an accumulative effect and after a sufficiently long period, or a sufficiently large number of encounters, the relative velocity of the one component with respect to the other will be large enough to lead to a disruption of the system. Since the effect will be more pronounced the greater the separation of the two components, we shall expect the time of dissolution to decrease with increasing size of the binary orbit.

From Chandrasekhar's analysis it follows that a binary with a mean separation of 100 AU‡ will be dissolved in about 2000 billion years, one with a separation of 1000 AU in about 70 billion years, and one with a separation of 10,000 AU in about 2 billion years. If the age of our galaxy were more than, say, 70 billion years, we might expect the distribution of binaries with separations larger than 1000 AU to be distributed according to an equilibrium distribution, which, according to Ambarzumian,[17] would mean an increase of number of binaries with increasing separation. This distribution is certainly greatly different from the observed

* As has been pointed out recently by R. Kurth, it is questionable, to say the least, whether an open system like our galaxy would ever attain a Maxwellian distribution. This difficulty also occurs in the discussion of clusters and of clusters of galaxy, but fortunately does not impair our conclusions.

† Bok lists the following four exceptions: the kinetic energies of early *B*-stars are too small; the kinetic energies of *K* and *M* giants are too large; the kinetic energies of cluster-type variables are too large; and, star streams exist.

‡ 1 AU (astronomical unit) = 15.10^{13} cm = mean distance of the earth from the sun.

TABLE 1

Method	Estimate of age	Condition at the beginning of the period
Cooling of earth's crust	2–4	formation of earth
Salinity of oceans	1–7	formation of oceans
Sedimentary rocks	~ 3–4	formation of oceans
U^{235}/U^{238} ratio in minerals	< 6	formation of earth's crust
U/Pb ratio in minerals	> 2	formation of earth's crust
Lead ores	3	formation of earth's crust
Moon	> 2–4	formation of solar system
Meteorites	> 0.06	formation of solar system
Stellar evolution	< 100	formation of our galaxy
Sun	~ 5	formation of our galaxy
Equipartition of kinetic energy	~ 2–4(?)	formation of our galaxy
Binaries	< 10	formation of our galaxy
Star clusters	~ 4–5	formation of our galaxy
Clusters of galaxies	~ 2–4	formation of the universe
Red-shift	~ 4	formation of the universe

distribution,[23] where the number of binaries rapidly decreases with increasing separation. From the observed distribution of binaries among the various values of their separation, we are thus led to an upper limit for the age of our galaxy of the order of 10 billion years.

Dynamics of Star Clusters

The stars in our galaxy often appear in groups. Here and there obvious *clusters* of stars appear, even to the naked eye. Some of these have been known since antiquity, such as the Pleiades and the Hyades clusters in the constellation Taurus, the cluster forming the constellation Coma Berenices, and the Praesepe cluster in Cancer. These belong to the group of galactic or open clusters, containing from a score to a few thousand stars. The distances between the stars in such an open cluster are relatively large. On the other hand, there are the globular clusters containing at least 50,000 stars that are all very near together. The nearest and brightest one of the globular clusters is situated in the constellation Centaurus. For our present discussion it is more convenient to divide the clusters into loose and dense clusters. Typical examples of loose clusters are the Taurus cluster, of which the Hyades cluster is the nucleus, and the Ursa Major cluster, whereas the Pleiades and Praesepe clusters and all of the globular clusters are typical dense clusters.

In a loose cluster the star density is so small that we may neglect interactions between cluster members and they will disintegrate partly because of "tidal" forces produced by the central mass of our galaxy,[16] and partly because of encounters with other stars that will dissolve a loose cluster in the same way as they dissolve binary systems. A quantitative analysis of these processes indicates that a typical loose cluster will disintegrate in a period of between two and three billion years.

The effects that lead to the disintegration of the loose clusters are unimportant in the case of the dense clusters. In the latter case the disintegration proceeds, since due to mutual interactions of the cluster members some of them will acquire sufficiently large velocities to escape. The disintegration is thus comparable to the loss of a planetary atmosphere due to the escape of the tail of the Maxwell distribution. Chandrasekhar[24] has shown that in the case of dense galactic clusters such as the Pleiades and the Praesepe clusters, disintegration will follow in a period of between three and six billion years. However, globular clusters have a much longer lifetime and can probably exist practically unaltered for as long as a few thousand billion years.

We see thus that both the loose and the dense galactic clusters are relatively short-lived organisms. The first category is subject to disintegration by galactic tidal forces and the second one to evaporation by internal interactions, and in both cases the mean lifetime of a galactic cluster is of the order of 2 to 3 billion years. Since there are at least several hundred galactic clusters in our Milky Way we are led to assign to our galaxy an age of at most 4 to 5 billion years.

Dynamics of Clusters of Galaxies

Just as stars appear in clusters in our own galaxy, so galaxies themselves can and do appear in groups. In this way our Milky Way is part of the so-called local group which consists of at least thirteen galaxies, or extragalactic nebulae. Our nearest neighbors are the two Magellanic Clouds, which are satellites of our Milky Way, and the well-known spiral nebula, the Andromeda nebula. The local group contains only a small number of galaxies, but there are known a number of clusters of galaxies that contain several thousands of galaxies—for instance, the Virgo and Coma clusters.

These clusters of galaxies will behave like dense star clusters, which means that due to mutual interactions some members of the cluster will acquire sufficiently high velocities to be able to leave the cluster. Their lifetime is, however, of the order of

few hundred billion years.[25] Since these clusters are a rather common phenomenon, we are led to an upper limit for the age of the universe of about one hundred billion years.

From a study of the density distribution in such clusters of galaxies, Omer[26] has come to the conclusion that this distribution is only compatible with an age of about 2 to 4 billion years.

The Expanding Universe

It is well known that monochromatic light emitted by a source moving away from an observer will show a shift towards the longer wavelengths. This red-shift is proportional to the velocity with which the source is receding. Since distant extragalactic nebulae showed such a red-shift, it was assumed that, indeed, these galaxies were moving away from us. The velocities of recession calculated from the observed red-shift turned out to be directly proportional to the distance of the nebula from us, as was shown by Hubble. The interpretation of this effect was that the universe as a whole was expanding from an original state of extremely high density. From the observed velocity-distance relation it followed that this expansion had started about 2 billion years ago. Recently, however, it was realized that the yardstick for measuring distances, which was based on the luminosity of the variable Cepheids, was wrong and the present estimate of the period evolved since the expansion started is about 4 billion years. It must be stressed, however, that the basis of these estimates is a homogeneous model of our universe. Our universe is certainly not a homogeneous system and Omer[27] has recently shown how much estimates of this kind have to be changed, if only the slightest inhomogeneity is admitted. It seems therefore that the estimate of an age of 4 billion years for our universe, based on the velocity-distance relation, is still far from rigorously established.

Conclusion

We are now in a position to collect all the data and to see whether they fit together. This has been done in Table 1. The first column gives the method used to obtain an estimate for the age of the universe, the second column gives the result in billions of years, and the last column indicates the period whose length is estimated.

To one's great surprise it turns out that the values in the second column agree remarkably well and all lead to the conclusion that a few billion years, say between 1 and 5 billion years, is the length of the present epoch. The data of Table 1 afford, as far as the present author can see, one of the strongest arguments against the hypothesis of continuous creation.[28]

Probably we can best end this paper as we started it by quoting Chandrasekhar.[1] "To conclude, then, we see that the geochemical evidence bearing on the age of the earth and meteorites, the galactic star clusters, the statistics of binary stars, the clusters of extragalactic nebulae and finally the system of the nebulae, all agree in pointing to a time scale of the order of a few billion years. It does not seem that this can be accidental."

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An Introduction to a Popularized Symposium on Evolution*

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When Mills College, in celebration of its centennial, decided on a biological conference which would be of interest to a general audience, the choice of an appropriate subject was not difficult. The biologist knows of many important discoveries made during the last century which inaugurated a new era in his science and made their imprint on it to last for a long time. Such was the rise of comparative anatomy and of comparative embryology in the sixties of the last century; the rise of cytology in the seventies; the rise of bacteriology and serology a little later; that of experimental embryology in the eighties and nineties; that of endocrinology mostly in this century; and the phoenix-like flight of genetics since 1900. But there is only one single generalization which has remained the center of biological thought since its final statement, only a few years after the foundation of this college. This is the doctrine of evolution as formulated by Charles Darwin in 1859. Vague ideas of the evolution of the cosmos, as well as of the world of living creatures, had been produced for over 2000 years since the time of Eratosthenes and Anaximander. Kant and Laplace had proposed plausible theories of cosmic evolution which are coming into their own again nowadays and Lamarck and Geoffroy de St. Hilaire had presented convincing ideas of organic evolution which were strange mixtures of deep insight and wild guesses. But Darwin's work struck like lightning biological thought, which was ready for the theory of evolution, because he presented together with the material in favor of evolution an elaborate and convincing theory in explanation of why evolution takes place. This brought home at once the truth of evolution to the biological profession. Furthermore, it gave them a central, pivotal idea which shed light on all the different phases of their work and actually forced them to measure the meaning of their work by the yardstick of the brilliant generalization.

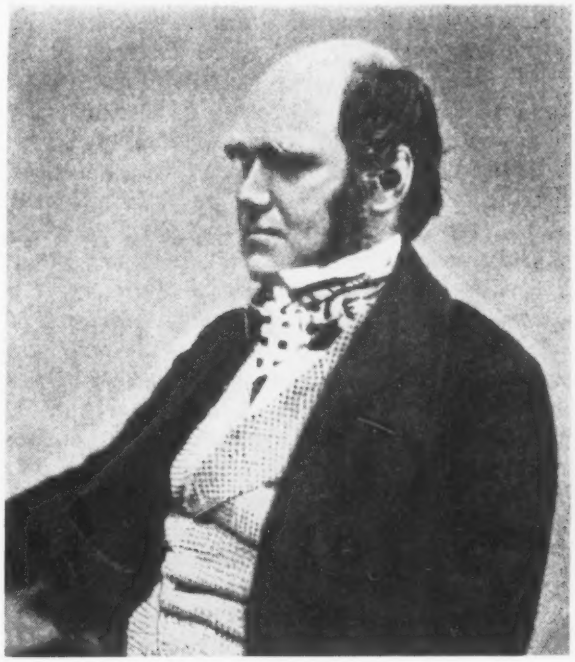
There are dozens of all-important scientific discoveries which failed to impress the thinking of their time outside of the profession, nay, even failed to come to the notice of the public. There is, for example, no public repercussion to the quantum theory, which has completely changed the physics and the natural philosophy of our time. But the doctrine of evolution, from the outset, affected the minds of layman and scholar, of naturalist, philosopher, law giver, theologian, sociologist, moralist, in short, of every thinking individual, and this

* This symposium for the layman took place at the centenary of Mills College, Oakland, California. The general introduction by one of the organizers is presented here.

p effect lasted from about a hundred years ago the present day. One potent reason for this is nd in the fact that man now became included the inexorable laws of nature, which led to his mocratic dethronement from the self-appointed e of master to that of an integral, though small, rt of nature. Another reason is that evolutionary nking opened a way to free the mind from medi- l fetters when it replaced self-perpetuating fan- es of prescientific times with natural laws ca- ble of study and analysis. Still another reason is at the type of thinking introduced by the new ght, namely, thinking in terms of change from simple to the complicated by the action of im- nent laws without guidance from without, sug- sted new approaches to almost every field of in- lectual endeavor.

Thus, for a hundred years, the doctrine of evo- tion has been the center of the biological sciences well as of much of the progressive thought in all her sciences, from chemistry to anthropology, to dicine and jurisprudence, to psychology and phi- sophy. There have been ups and downs, peaks nd valleys, as in all actively progressing fields. here have been days when a book with the title *the Deathbed of Darwinism* could be printed nd taken seriously. There have been days when ymen and fanatic partisans of some credo tried burn the doctrine of evolution at the stake. here is not much left of this today. Within the ological profession the study of evolution is now aybe at the highest peak ever reached, and out- de of the profession even the strongest opponents ave made their peace with the doctrine, though serving for themselves some points of a meta- hysical nature outside of the realm of biological search.

The present-day theory of evolution is, as might e expected, in many respects highly technical. No- ody within the biological sciences would think of eneralizing in this field without a knowledge of eology and paleontology, comparative morphology nd development, taxonomy and ecology, cytology nd genetics, mathematical statistics, and even iochemistry. But this does not mean that the es- entials could not be presented to a cultured au- ience without going into the technical details and ithout discussing still controversial points. This s exactly what this centennial program will try to do and, I hope, will succeed in doing in spite of the ormidable array of leaders in the different fields ho will be the speakers. Thus it is my duty, as a ind of keynote speaker, to sketch, in quick out-



Charles Darwin

lining strokes, the quintessence of present-day evolutionary thought. The details of this portrait will be painted afterwards with loving detail by the group of jubilee lecturers.

The theory of evolution is a biological theory, not a philosophical one. It is a generalization meant to explain the features of the organisms of the present and the past by the history of their ancestors and as a result of the action of natural forces within and without the organism in the course of time. In this statement the emphasis lies upon the words *biological* and *natural*. The scientist can work only with data which are derived from observation and experiment and which can be checked, measured, analyzed, confirmed and, in the case of the experiment, repeated. Thus his work is both factual and pragmatic. The basis of his work is the belief that the facts he deals with can be understood within the known or still to be discovered phenomena of nature which resolve themselves in the end into the basic notions of physics and chemistry. If he meets with difficulties, as invariably he will, he hopes for a future solution in the same basic terms, and he works toward this goal. He refuses to take refuge in metaphysics, believing this to be scientific defeatism. It is well known that in this attitude he is opposed, sometimes by outsiders and occasionally also by an insider with an inclination toward mysticism. The biologist's answer is this: more observation and more experiments.

Actually the theory of evolution has, since its origin, been especially favored by the attention of groups who tried to introduce metaphysical ideas into a field which should belong to the naturalist. Such writers frequently had great success with the layman, who tends to be impressed by such vague ideas as "creative evolution" or "holism," ideas which try to solve real difficulties of scientific analysis by a meaningless metaphor which cannot be proven or disproven, checked or analyzed, or even described unequivocally. The names of Bergson and Lecomte du Noüy will suffice as two examples among many. Be it stated therefore, at the outset, that such ideas, whether coming from philosophers, novelists, naturalists, theologians, or even great statesmen, have never helped our science to make the smallest step forward into unknown territory. They have never done anything but replace temporary ignorance by an appeal to unknown, supernatural forces or agents, and lure untrained minds into the self-deception of mistaking a cleverly circumscribed confession of ignorance for a deep insight and explanation. Therefore the overwhelming majority of students of evolution leave aside creative evolution, finalistic causes, emergent evolution, entelechies, and similar intangible word-plays, and continue to do their work.

By evolution we mean here the evolution of the living organisms from their beginnings up to the highest types like flowering plants, insects, man. But there is also an evolution of the atom, of the elements, of the complicated molecules, of the cosmos, of the solar system, and finally of the earth. Here we consider most of these facts of inorganic evolution as generally given. But some of them are closely linked with our study of organic evolution, furnishing, as it were, the backdrop to the stage upon which the evolution of the organisms has taken place. Thus our first topic is this: The starting point for the evolution of the living world. Evolution from the first beginnings of life to man requires time, much time. Therefore, our first problem is whether the development of our planet has taken enough time to give organic evolution a chance. Today we have really good information about geological time, which turns out indeed to be long enough for evolution to take place, and the first speaker, a distinguished geologist, will tell us the important facts.

Given the time required for finishing organic evolution, the next requisite is to have it start, which requires the presence of the proper physical and chemical conditions for the origin of life. I have seen the time when such phantasmagories as a "primordial mucus," from which the first cells originated, were taken as scientific theories. Since that time chemistry, physical, and colloidal chemistry, and biochemistry have taken over, and though they have not yet solved completely the old puzzle of the origin of life, it no longer appears so formidable. The second speaker, a famous biochemical geneticist, will give you authoritative information on this great problem.

Given the chemical evolution of living substance, we are anxious to know how the simplest living molecules, if we may use this not very satisfactory designation, may have turned into organisms. Again we do not have the solution as yet. But there are organisms known, namely the viruses, of such relative simplicity in a chemical sense, though quite complicated in a biological sense, which furnish interesting information about the beginnings of life. You will have the pleasure of studying this problem under the guidance of the father of modern virus research. Thus the first three papers will furnish the background for the stage upon which evolution of the living world has taken place and perhaps still is taking place.

The next major section of evolutionary fact and thinking may be entitled "Evolution as a fact." We know with certainty that all the manifold facts of biology lead inevitably to the conclusion that all organisms are the products of past evolution, which has built up the higher types out of lower ones. Thus the present living world may be represented as the top branches of an evolutionary tree. Though this is a logical conclusion from the analysis of a myriad of facts, it is still a historical conclusion, not an observed fact. Fortunately there is a science which is able to observe the progress of evolution through the history of our earth. Geology traces the rocky strata of our earth, deposited one upon another in the past geological epochs through hundreds of millions of years, and finds out their order and timing and reveals organisms which lived in all these periods. Paleontology, which studies the fossil remains, is thus enabled to present organic evolution as a visible fact, and a renowned representative of this discipline will make you partners of this knowledge.

Having thus established evolution as a scientific fact, we turn to the third major chapter, the one dearest to the biologist proper, the great question: What causes evolution to take place?

In the introductory remarks we mentioned the fact that Darwin is the actual father of the theory of evolution, because, unlike his predecessors, he found the explanation for evolutionary change.

Much has been learned since without changing the general principles discovered by Darwin. The details have been modified, less clear notions replaced by clearer ones, new methods of study introduced, and basic discoveries in newly developed biological fields have been made. This has enabled the study of evolution to develop into a modern, flowering, and exact science. The basic concepts of Darwin which have stood the test of time are the following:

1. Organisms show variation. This means that in a population of many individuals of the same species small differences between the individuals are observed in regard to a number of characters. Some individuals are, for example, a little larger, others a little smaller than the typical size of the species. Some are darker, others are lighter, some are more fertile, others are less fertile. Frequently these differences are hereditary.

2. Of all the offspring of a pair of organisms only two can survive under normal circumstances to replace the parents, thus keeping up the equilibrium between different organisms, predators, and prey. This has also been called the struggle for existence, though not intended in a literal sense.

3. Within a varying population which is as a whole well attuned to its normal environment—a condition which is called adaptation—some of the variants fit better, others less well, the milieu. The better-fitted ones have a greater chance to survive and to propagate their kind (provided their superior traits are hereditary) than the less well adapted ones. This is called the survival of the fittest by means of natural selection, with its corollary the destruction of the less fit ones. Natural selection, much misunderstood in early Darwinian days, is thus not an abstract principle which produces or creates something. It is nothing but a name for the fact that certain hereditary types within a definite environment have a greater chance of survival than others.

4. Natural selection, working upon hereditary variants in a mixed population, thus can replace one type by another, and if this continues for many generations a very different new type may evolve —a new species.

It is our intention to show, in the following group of lectures, what form this basic Darwinian doctrine has assumed after almost 100 years of study, how it was made specific, freed of ambiguities, and underpinned with a huge construction of observation and experiment.

The basic fact of evolution is hereditary variation. Evolution, which, after all, means change from one heredity to another, is not possible without the appearance of different types. This is hereditary variation. Non-hereditary variation, which also exists, is left out here because it does not contribute to evolution. Nowadays, we call hereditary variation "mutation" and such a variant a "mutant." We know also to a considerable extent what mutation is. It is a sudden change in the framework of the chromosomes within the nucleus of the cell. If the tiniest section of a chromosome which is capable of changing (mutating) is called a gene, mutation produces the mutant gene which controls a new, different character. The mutated gene always reproduces its kind, and a new hereditary type has arisen. We know further that mutation is constantly occurring within a population, possessing a known frequency for each individual sort of gene, and we know that mutation can be experimentally increased by powerful radiations or chemicals. The geneticist, in producing and analyzing mutation and simultaneously weeding out non-hereditary variation, is thus able to give Darwinian variation a definite, exact meaning, as one leading geneticist will soon tell you in more detail. It should be added that in the firmly established group of facts to be presented by different speakers no room is left for an assumed heredity of direct environmental effects. Only mutation, caused by still unknown spontaneous happenings within the architecture of the chromosomes, can result in a new heredity.

In a freely interbreeding population of a species of animals or plants in which mutation occurs of one or the other gene with a definite frequency, it can be calculated how frequent the mutant will be in a population of known size after a certain number of generations. This is possible because all mutant genes are inherited according to Mendel's laws, which show that the genes are handed around and sorted out in the offspring of two different parents according to simple statistical rules. Thus the geneticist has established one aspect of what in Darwin's time was called variation.

This becomes still clearer if we look at the fate, not of a single mutant in a population but of many of them together, which is the actual situation, because all kinds of genes show the phenomenon of mutation. Again, genetics has established the facts. One of the consequences of the laws of Mendelian inheritance is that in the offspring of a pair of individuals differing in a number of pairs of genes these will be reshuffled in such a way that all possible combinations appear in definite numerical ratios which are controlled by simple statistical laws. In a mixed interbreeding population, finally,

there will be established an equilibrium, meaning that the different mutant genes and their haphazard combinations in all possible assortments will be present in definite numbers which can be calculated. One calls such a shuffling and reassortment of different genes "Mendelian recombination." Thus we see that hereditary variation in a mixed population means not only the presence of individual mutants but also of an array of mutant recombinations. As mutation occurs all the time, though with a small frequency, and as free interbreeding of the many individuals within a population results in recombination of mutants, any normal interbreeding population of any organism will contain an array of hereditarily different forms, the relative numbers of which are controlled by the rate of mutation and the statistical consequences of breeding. This will occur if nothing interferes with the working of pure chance, which is the meaning of the words: "statistical consequences." This, then, is the real sense of what Darwin vaguely had to call "variation." I trust that you will hear more of it in the geneticist's paper and that these facts will come up again in many of the further discussions by various lecturers in connection with different aspects of the problem.

Thus far we have looked at populations of individuals within one species with the eyes of the geneticist. But it is also possible to study them with the methods of the taxonomist, i.e., the student of animal and plant systematics; or with the outlook of the ecologist, who studies the relations of the organism to its environment; or with the experiences of the animal and plant geographer who studies the distribution of the organisms in space. All these sciences, which will be represented later by prominent spokesmen, for both the animal and plant kingdom, have assembled the next important set of evolutionary facts, which assume special significance if interpreted by the results of genetics. The taxonomist finds that the species is not a simple, invariable unit. Actually within the species lower entities can be isolated, the subspecies, which can be described and recognized by definite characters which are hereditary and are based, as the geneticist could show, on Mendelian mutants and their combinations. These subspecies occupy definite geographic areas within the distributional area of the whole species, and they are characteristic of their area. As all subspecies are fertile inter se when crossbred, hybrid populations may occur where the subspecific areas meet. Further study reveals that the subspecies, though as a rule the last unit which the systematist labels, are not necessarily uniform themselves. Actually still smaller units may be distinguished, occupying subareas, and even within these, genetically different isolated colonies may exist. Thus there is no limit in principle to the genetic and spatial subdivision of the species, though in nature some forms may be more subdivided, some forms less subdivided.

At this point the ecologist enters the picture. In studying the organism in its environment he realizes that many, if not all, traits which characterize these subdivisions are of an adaptive nature. This means that the observed trait or combination of traits enables the organism to live in a definite environment or habitat. The prostrate growth, time of flowering, and life cycle, all of them hereditary traits typical for an alpine plant, enable it to thrive in the peculiar alpine environment. With alpine or desert forms, or other groups peculiar to an extreme environment, this is easily seen and also proved. The respective subspecies or still lower unit is clearly adapted to the specific environment. It is an ecotype, as it is called. Though this is not always so obvious, a closer study frequently reveals that traits which at first sight seem hardly to have any meaning for the welfare of the organism, are in fact one conspicuous facet of a complex of physiological conditions, themselves highly adaptive. Such adaptive physiological traits as, say, tolerance or need for a certain chemical, are recognizable only when properly studied, at which time they may turn out to be the real thing hidden behind an unimportant, concomitant, visible character.

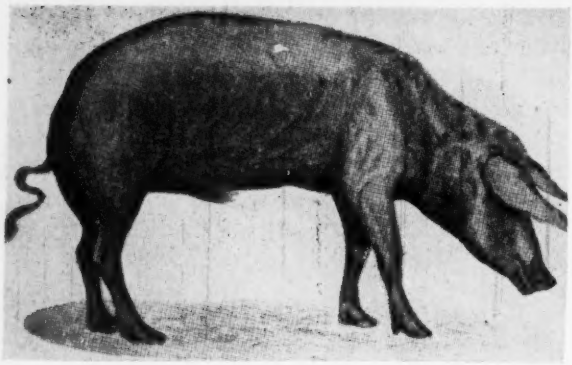
With the statement of these facts, which will come up again in many of the subsequent papers, especially those by the taxonomists and ecologists, we have reached the next problem of evolution, after the prior analysis of genetic variation. How does evolution—thus far still below the level of the species—produce the different subspecific or still lower forms which are adapted to their environment by heredity? The same question, of course, appears also upon the level above the species, as species, genera, or families are also adapted to their specific surroundings: think of a woodpecker or a sea lion adapted to its peculiar mode of life. The process of evolution which involves adaptation and the occupation of diverse geographic or environmental areas may be called adaptive radiation, and the specific environment to which the adaptation has taken place is called the environmental or ecological niche. Adaptive radiation then puts the taxonomic groups into their proper ecological

niche, and you will hear of interesting examples in the papers of botanical and zoological experts in this field.

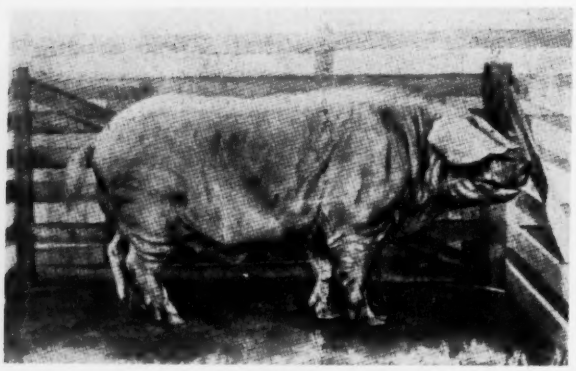
The old Darwinian answer to this problem would have been: selection is the cause of adaptive radiation. Though this is true as it stands, we require a more detailed explanation in harmony with the genetical facts. This has been found and is actually a very simple one. We saw that in an interbreeding population of a species a whole array of mutants and their recombinations are always present. They are perpetuated in the population if they are not deleterious or inferior in some way. In the latter case they are weeded out by selection because they cannot compete with genetically better-fitted brethren. But there are even definite statistical conditions known in which somewhat inferior mutants and combinations may carry on in the population. Whatever the details of all this, populations will always contain numerous different combinations of genes. Among all these genetical variants some will be of a kind that would enable them to live in another ecological niche, and as soon as they get there by whatsoever chance—say by migration or by change of the local climate, soil, or food—they are adapted to the new niche. The niche then does not make the form adapt itself to its features, but a chance preadapted variant enters its proper niche. Life in a cave does not make animals blind, but genetically blind animals find their way into caves where their disability is not at a disadvantage; or animals that can see become cave dwellers, in which situations mutations that impair their vision are no longer disadvantageous and may become fixed characters of the population. Thus mutation, genetic variation in a population, preadaptation, and adaptive radiation explain the taxonomic, geographic, and ecological picture found within the species. We may add that, once given the origin of diverse species of different genetic constitution, the same reasoning applies also to the explanation of *their* occupation of definite niches.

With the last phrases we have approached the next problem. The categories below the species are completely fertile inter se as well as intra se. But species, certainly in the animal kingdom, are intersterile or produce sterile offspring, some exceptions notwithstanding. Species, then, are genetically isolated, and our former deductions regarding the happenings within the species, which are based upon free interbreeding or, as this is sometimes called, upon gene exchange, do not apply any more to the relations between species, whether they are "ecospecies" occupying different niches or species living side by side in the same habitat (sympatric species). The evolutionary step from one species to the next one involves thus another evolutionary principle. This is isolation. This may mean physical isolation by any macro- or microgeographical, or ecological barrier. It must mean in any case genetic isolation by hereditary, morphological, physiological, or psychological barriers. This includes the presence of mutants for incompatibility on a morphological, physiological, or psychological basis; as well as chromosomal differences which prevent normal cellular behavior of the hybrid and therewith produce sterility, or serological differences. There is no difficulty in visualizing genetic isolation appearing by chance mutations and recombinations between groups which had first been physically isolated. There are many geneticists and taxonomists who assume that the best chance for accomplishing an isolation of genetic groups within a species, thus raising the genetically isolated groups to the rank of new species, is present when subspecies are adapted to very different environments and are physically prevented from interbreeding for a long time, say, subspecies occupying the extreme ends of a geographic series. There are difficulties encountered when one tries to work out the details of such evolutionary happenings, and there are still greater difficulties when one tries to make such happenings the prototype of the origin of new species. But this is not the place to discuss controversial subjects. A variety of the facts as found in specific cases will come up in the lectures of the taxonomists and ecologists.

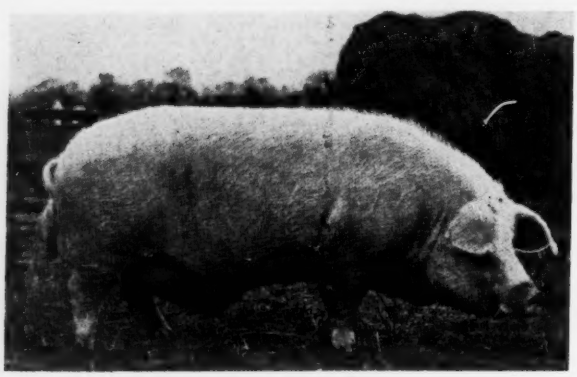
Genera, families, orders, and classes are called the higher systematic categories, and the evolutionist has to explain how species are transformed into genera and how genera are transformed into families, etc. The Neo-Darwinians, following in Darwin's footsteps, take it as granted that the slow accumulation of mutants and their recombinations within the different species slowly transform these into higher and higher categories by means of preadaptation, selection, and adaptive radiation. It is at this level that difficulties arise for the Neo-Darwinian viewpoint, which is derived solely from happenings in interbreeding populations within the species. To mention only one point: in Darwin's time it was frequently emphasized that complicated adaptations can hardly be built up in small steps favored by selection because selection cannot favor a new adaptive character before it has reached a functional level. Take the origin of whalebone whales with their amazing mode of feeding, based



Boar from the middle of the 18th century



Boar from about the year 1900



Boar from 1935

The development of the Danish Landrace. Scientific breeding was carried out to develop a pig that satisfies the producer in regard to fecundity, one that has the ability to yield large and well-developed thriving litters, and, at the same time, one that satisfies the customer in regard to quality.

Photographs from *Denmark Agriculture*, p. 224, The Agricultural Council, Copenhagen, 1935. Reprinted with permission.

upon the giant strainer of their whalebone-covered jaws. They must have evolved from toothed whales, and their embryos still develop first non-functional teeth. Is any transitional series of small steps between the two groups imaginable? Innumerable comparable cases have led some evolutionists to ask themselves whether additional evolutionary happenings exist that solve the difficulties created by the Neo-Darwinian tenets for understanding macroevolution as opposed to microevolution. The solution is found in the assumption of large mutations or saltations, meaning mutants which affect basic processes of early embryonic development. This results in major changes of subsequent development affecting many parts of the organism at once and producing a completely changed but still harmonious organization by means of the known regulatory embryonic potencies. Facts in favor of this hypothesis and examples for it are accumulating. But this is a highly technical subject which we are satisfied only to mention.

It is obvious that a complete study of evolution will embrace many sidelines or additional information, which I have not mentioned in this rectilinear introduction to the conference. However, some of them will be presented in three subsequent lectures. There is first one type of evolutionary process, probably almost confined to the plant kingdom, in which an interesting special behavior of the chromosome set is the agent of evolution. In the last paper on the program this fascinating subject will be presented by an outstanding authority. Because we are people, some of us at least are more interested in man than in flies and flowers. The doctrine of evolution touches human affairs in many fields. There is, of course, the evolution of man from his animal ancestors and the difficult problem of evolution of the human mind. At least another day would be needed to discuss this topic. There is further the known and visible evolution of domestic animals and plants, which had already made such a great impression upon Darwin. We shall learn from the mouth of an eminent investigator, of today's aspect of the important problem, at least in plants, where spectacular insight has been gained. Finally, man's breeding and providing of his animal and plant food is a major feature of his own cultural evolution, and it appears appropriate that a lecture on this interesting topic by the best man in the field will follow the banquet.

Mills College has developed in the course of a century from simple beginnings to an educational

institution of national standing. Almost the same century has seen the development of the doctrine of evolution from Darwin's first approach, to a major field of research which is still continuing and expanding in scope. In arranging this conference on this festive occasion, the biologists assembled here wish to congratulate their host, Mills College, on its great performance and to express their confidence that it can look forward to another century of progressive evolution, whether in the Neo-Darwinian way by slow accumulation, or in the saltational way by leaps and bounds.

TWO OPPOSING LAWS

Two opposing laws seem to me now in contest. The one, a law of blood and death, opening out each day new modes of destruction, forces nations to be always ready for battle. The other, a law of peace, work and health, whose only aim is to deliver man from the calamities which beset him. The one seeks violent conquests, the other the relief of mankind. The one places a single life above all victories, the other sacrifices hundreds of thousands of lives to the ambition of a single individual. . . . Which of these two laws will prevail, God only knows. But of this we may be sure, that science, in obeying the law of humanity, will always labor to enlarge the frontiers of life.—Pasteur, on the occasion of the opening of the Pasteur Institute, November 14, 1888.

The Geneticist's Analysis of the Material and the Means of Evolution

CURT STERN

The author was born and educated in Germany where he received his Ph.D. in Zoology at the University of Berlin (1923). From 1924 to 1926 he was a Rockefeller Fellow studying Drosophila genetics in Thomas Hunt Morgan's laboratory at Columbia University. His brilliant demonstration of the cytological basis of crossing-over formed a landmark in the general acceptance of the Chromosome Theory of Heredity. Since 1932 he has been a resident and, in time, a citizen of this country. For many years at the University of Rochester, he is now Professor of Zoology at the University of California. His main interests are in the fields of General Genetics and Human Genetics. His recent book, Principles of Human Genetics, *is recognized as authoritative in that field.*

WHEN the modern student of the evolution of stars approaches his subject, there dissolves before his mind the image of great suns and the beauty of the heavens. Instead, he delves into the properties, energy exchanges, and transformations of invisibly small elementary particles, electrons and protons, neutrons and atomic nuclei and a host of other physical units in order to derive from the knowledge of their interactions the majestic events of cosmogony. Likewise, when the geneticist enters the study of organic evolution there fade into the background the formed products of the history of life, the animals and plants whose complexity and interrelationships first posed the problem of evolution. Instead, there appear on the scene elementary units, the genes, whose properties, energy exchanges, and transformations are thought to account for the miraculous spectacle which life has played on our globe.

If the undertaking of the astrophysicist seems audacious, what adjective should one apply to the attempt of the geneticist? Atoms and electrons are accessible to direct study by themselves, and the extrapolation to cosmic events of knowledge thus derived is a reasonably safe step. However, while separate physical particles exist independently of formed physical bodies, naked genes are not known. Genes are always parts of an organization, of cells, whether they function singly or as parts of multicellular plants or animals. The properties and actions of genes thus can be investigated only within the complex, historically conditioned organisms themselves. The elements we employ in order to explain evolution are themselves encased in that which needs explanation!

This indeed makes a complicated problem more complex yet, but it does not make it inaccessible to analysis. Let us then see how the geneticist—or at least many a geneticist—analyzes the material and the means of evolution.

To the geneticist the material of evolution is not the organism as a whole but its hereditary basis, that which Weismann called the germ plasm. Weismann's distinction between the soma, the body, and the germ plasm, with its implication that the former is a passing, mortal structure while the latter is the lasting and biologically immortal material, is not a philosophical abstraction but the formulation of observable facts. Every organism which has developed from a fertilized egg owes its bodily structures, so similar to or identical with the structures of his parents, not to some strange process through which the eyes, the limbs, the internal organs of the parents gave rise to the eyes, the limbs, the internal organs of the child, but to a still more

miraculous process through which these parts of the child's body were recreated by the activity of the genetic material in his germ plasm. The bodies of our parents, our own bodies, and those of our descendants are the ephemeral creations of the inconspicuous genetic material. This genetic material, we now know, is largely contained in the nucleus of the cell and, more specifically, in the chromosomes. The analyses of Mendel and his illustrious followers have demonstrated that this material is subdivisible into units which we call genes. While it is a problem of great importance, and one not yet fully solved, whether these units are independent of each other in the sense that each can exist and act within the cell as a separate structural entity or whether they are parts of larger units, we shall here adopt the former view, which has much to support it. We thus think of the genes as structures linearly arranged within the chromosomes.

What do we mean by the word "structure" as applied to a gene? An answer to this question is provided by a consideration of the size of genes. We have various means of estimating the number of genes present in a nucleus. While these estimates are based on several unproved assumptions that do not permit us to place too much reliability on the results, they all agree in leading to a number of, at least, several thousand genes per chromosomal group. From such estimates of total number of genes, it is easy to derive the maximum average volume of a gene. One has only to divide this number of genes into the measurable volume of the chromosomal group. If the chromosomes consist of nothing but genic substance, the resulting figure is the average volume of a gene. If the chromosomes consist of both essentially genetic substance and of accessory material, then the average volume of genes is, of course, smaller than calculated. The outcome of such calculations is clear. Genes are entities whose size is at the molecular level. Whether this means the level of macromolecules consisting of millions of atoms which are perhaps divisible into many identical smaller molecular subunits, or whether this means the level of more conventional organic molecules is a question of secondary importance to our discussion. The essential discovery is that the units of the germ plasm are not any more living units themselves in the sense in which a cell is a living unit, but that they are molecular elements which do not possess properties of life but only properties of chemical compounds. The miracle of their coordination in the organization of a cell the evolutionary geneticist largely leaves aside, taking it for granted himself, and turning it over for analysis to the cell physiologist and the student of development.

Gregor Mendel

From an evolutionary standpoint the basic fact about genes is that each one of them is descended from another gene. Genes arise only by reproduction of formerly present genes. "Reproduction of genes"—this concept needs clarification. For genes as molecular entities reproduction is essentially unlike the process by which a complex whole organism delegates the power to a part of itself to continue the existence of the species. Genic reproduction consists in the biochemical processes, still largely guessed at, by means of which a gene molecule assembles molecular parts from its cellular environment and organizes them into a copy of itself.

The continuity of the germ plasm has become the continuity of genes. Weismann believed, on the basis of certain accurate observations in special groups of animals, that the continuity of the germ plasm was assured by the setting apart, during development, of special cells which would preserve the totality of the genetic material and later become the germ cells of the adult. His theory of development assumed that the body cells were genetically incomplete, having received only various fractions of the total genetic materal of the egg from which they derived. We are now inclined to think that all cells of an organism contain in their nuclei essentially replicas of all the genes with which its develop-

ment began. Why, then, are not all cells capable of continuing the chain of generations, i.e., why can they not all function as germ cells? There are some organisms in which this question need hardly be asked because reproduction *can* occur from body cells as well as from germ cells. Asexual reproduction, from groups of body cells as well as from single cells, is known from numerous invertebrate animals and from all groups of plants, giving proof of the continuity, by molecular synthesis, of the genes not only through germ lines but also through somatic tissues. Yet it remains true that the majority of body cells seem incapable of serving as bridges from one generation to the next.

The reasons for this remain obscure. The specific differentiation of the body cells, it is said, inhibits their genic content from expanding its activity toward the fuller realization of its developmental potencies. How this inhibition is actually produced is one of the riddles of differentiation. Interestingly enough, some modern theories of differentiation make use of concepts similar to Weismann's. The recent evidence concerning the existence of extra-chromosomal, extra-nuclear gene-like elements in the cytoplasm of cells has led to the suggestion that the germ cells retain complete assortments of all possible kinds of such cytoplasmic genic elements, but that these elements are distributed differentially to the various types of body cells so that these are no longer totipotent. At present we do not know enough about these extra-nuclear genetic units to evaluate their general role. We shall leave them out of consideration in the rest of our discussion, at the risk of having to regret this omission at some later day.

The descent of all existing genes from previously existing ones is the basis of the continuity of living forms—but evolution requires continuity plus change. We must therefore explore the ways in which a descendant may receive a different genetic makeup from that of a parent. We may distinguish two different ways, a conventional and a revolutionary one, without implying that the consequences of one way are greater than those of the other.

The conventional way rests on the exploitation of available resources. The cellular processes involved in the formation of germ cells and in their fertilization bring it about that the great majority of all organisms contain in most of their nuclei two like chromosomes of each kind which is characteristic for their species. One of each pair of chromosomes comes from the father, the other from the mother. Since each kind of chromosome carries a linear series of many different genes, one only of each kind being represented, and since these different genes are all characteristic of their chromosome, it follows from the presence of pairs of chromosomes that most nuclei contain pairs of each kind of gene, one member of the pair having been derived from the father, the other from the mother. These pairs of genes, all of which differ strikingly from each other, pair for pair, are usually designated by different letter-symbols, as, for instance, one pair by *A*, another by *B*, a third by *C*. In addition, the two members of any one pair often show a difference between each other, a difference which may be symbolized by calling one member of the *A* pair A^1 and the other A^2, or one member of the *C* pair C^1 and the other C^2. The chemical analysis of the genes has not gone far enough to give us a well-founded picture of the differences between genes belonging to different pairs and those belonging to the same pair. One suspects that genes of different pairs represent rather fundamentally different molecular structures while the different partners of the same pair are distinguished by only minor variations of a basically similar molecular pattern.

The existence of such variations between members of genic pairs forms a rich source of hereditary differences between parent and offspring. The well-known ways of endowing the mature egg or sperm cells with genes work in such a manner (1) that every egg or sperm cell receives one and only one partner of each genic pair carried by all other cells of the germ-cell-forming individual, and (2) that all possible combinations of different partners of the different pairs are formed. If, for example, an organism carries A^1 and A^2, two like partners B^1, and C^1 and C^2 among its thousands of genic pairs, if he thus is $A^1A^2B^1B^1C^1C^2$, he then may form germ cells of all possible four different combinations, namely $A^1B^1C^1$, $A^2B^1C^1$, $A^1B^1C^2$, and $A^2B^1C^2$. If he carries two variations of the genes of three different pairs, his germ cells may be of $2 \times 2 \times 2 = 8$ different constitutions; if he carries two genic variations of still as few as 25 different pairs he may produce $2 \times 2 \times 2 \ldots = 2^{25} = 32{,}555{,}432$ different germ cells! This simple process of reshuffling a relatively small number of alternatives in order to get large-scale variation is used by nature as well as by planning men. A building contractor who proposes to build whole tracts of houses of basically identical design frequently offers his clients choices in minor items, as for instance, steel window frames vs. wooden sashes, front or back porch, corner or side window, gas or oil heating, stucco or brick surface. With only five alternatives he can satisfy 32 different demands. Moreover,

some of the alternative combinations of features may make the houses appear so different as to obscure their basic similarity.

The mechanism of forming new combinations from the available resources of different varieties of the genes of each pair is employed in double fashion in the formation of sexually produced organisms. Both parents usually contain two varieties among the partners of many genic pairs. Moreover, the two varieties of a father's pair, for instance, A^1 and A^2 are frequently different from those of the corresponding pair of the mother which therefore may be designated as A^3 and A^4. Such parents will produce four different kinds of offspring, all different from themselves, namely, A^1A^3, A^1A^4, A^2A^3, and A^2A^4. If the two parents contain four different genic varieties for, let us say, 200 genic pairs there will be possible $4 \times 4 \times 4 \times \ldots = 4^{200}$ different genetic constitutions among the offspring. You may be tired of seeing me pile up large numbers, but there is a reason for doing this. The number 4^{200} is not simply larger than any possible comprehension but has a property which is relevant to our biological theme. The number is far larger than the sum of all individual organisms of all kinds that ever lived on the earth. This means that the production of hereditarily changed offspring by means of recombining the available genic varieties of the parents has actually realized only an infinitesimally small fraction of the possible types of organisms which could be born to a single pair of parents. The exploitation of the available resources for the creation of hereditary changes has hardly gone below the surface.

There have been some geneticists who were so impressed by these considerations that they regarded the endless recombinations of existing genic varieties as the exclusive material of evolution. This extreme view was never held by many and, at present, is probably not held by anyone. It would imply that all species contain exactly the same number of genic pairs and that their ultimate common ancestral form not only itself contained that full number of genic pairs but also all varieties of any genic kind which are now found separately in different species. Where the corporate genic content of two present species, II and III may be represented by:

II: A^1, A^2, A^3, A^4; B^1; C^1, C^2; D^2 . . . and

III: A^5; B^2, B^3; C^3, C^4, C^5; D^2 . . .

their common ancestor, I, would have had to be, at least:

I: A^1, A^2, A^3, A^4, A^5; B^1, B^2, B^3; C^1, C^2, C^3, C^4, C^5; D^2; . . . .

There is much validity in a notation such as the above. It pictures the established facts that each species contains an array of varieties of many genes; that different species may have certain genic varieties in common; and that different varieties may be substituted in one species for those present in the other. Yet while it contains the truth, the scheme certainly does not represent the whole truth—to borrow a legal phrase whose meaning to a scientist must be highly relative in spite of its verbal absolutism.

One of the difficulties of the scheme is that it fixes the number of genic pairs as equal for all products of evolution. While this may perhaps hold for certain short branches or twigs of the tree of life, it seems most unlikely to be correct for its larger expanses. Surely it cannot be true for that part of evolution which is closest to the origin of life! Another difficulty of the scheme is its feature of endowing the ancestral species with all the genetic material which the descendant species obtain only in divided-up fashion. The idea that evolution at large consists in the unscrambling of complexity rather than in its creation runs counter to our general impression and our basic expectations.

The geneticist has ways out of these difficulties. He has been witness not only to the conventional mechanism of genetic change, the recombination of available genic material, but also to ever-recurring revolutionary processes which change the nature and numbers of genes. These processes he calls mutations.

We now have numerous, carefully controlled observations, in bacteria and protozoa, multicellular plants and animals, including man, of the sudden, unexpected production of a new variety of a gene from an old one. A gene of the variety A^1 which for many times has faithfully reproduced its own kind may give rise to one specimen of variety A^2 or A^x. This new variety A^2 or A^x will now faithfully reproduce, for many times, its own kind, but some day in its turn it will give rise to one specimen of a still other variety, A^3 or A^y or, possibly give rise to the original variety A^1.

Not only the fact of occurrence of these mutations is established, but also its frequency has been measured. Different genes have different rates of mutation but a range of from 1 mutation in 10,000 reproductive steps of a gene to 1 in less than 1,000,000 includes most of the known rates of mutations. The stability of most genes, in terms of faithfulness in their reproduction, is high, even with the lowest rate mentioned: 1 mutation in 10,000 still means a rate of stability versus change of 9,999 to 1. But from the point of view of evolution the apparently low instability is of considerable consequence. With an intermediate rate of 1 mutation in 100,000, a

species like *Homo sapiens* which occurs at present at a population size of somewhat over two billion individuals will release each generation more than 40,000 newly mutated genes per genic pair into the species' pool of genic varieties. There is then no theoretical need of endowing a given species with all the genic varieties which its evolutionary descendants will possess. By means of new mutations the future will take care of itself.

Gene mutation provides manifoldness for new combinations. What processes bring about changes in the total number of genes? Genes are part of chromosomes. Any events which change the number of chromosomes in a cell, or add or subtract sections of chromosomes, are therefore changing the number of genes. Chromosomes normally double between nuclear divisions, and sister duplicates get distributed to sister nuclei. Any mishaps in the distribution may lead to new genic numbers. Thus if all duplicated chromosomes are kept together in a single nucleus the total gene number in that nucleus is doubled. Or, if normal distribution to the nuclei takes place in regard to most, but not all, chromosomes, one nucleus may get more than its standard share of genes, and the other correspondingly less. If similar anomalies happen during formation of the nuclei of egg or sperm, too many or too few of the parental genes may be handed down to the offspring. Sometimes a chromosome loses a part, be it an end segment or a section from its middle. Thus cells may be formed lacking only a few genes normally present. Sometimes the "lost" region becomes in reality joined to another chromosome. In such cases, fertilization may result in offspring with a few additional genes present as compared to the parents.

All such changes in genic numbers are self-duplicating. The mysterious regulation which coordinates the duplication of all chromosomes and their genic material so that they all just double from mitosis to mitosis applies likewise to nuclei with changed chromosomal or genic number. The extra genes are reduplicated regardless of the fact that they are extras, and the loss of genes is no incentive to the cell to make up for it by more than duplication of the remaining genes.

The fact that gene mutations as well as chromosomal changes once having occurred are reproduced in their own form makes the distinction between the two at times very difficult. Coarse chromosomal changes involving whole chromosomes or large sections of them are of course easily discoverable under the microscope, but many chromosomal changes are very small, some of them discernible as minute losses or duplications with the best optical equipment only, and only in cells with unusually large chromosomes. Whenever the microscope fails to show a chromosomal change the question arises whether a submicroscopic change involving a whole gene or whole genes has occurred, or whether a real gene mutation, an intragenic change, was present. One answer to this question suggests that the question itself is wrongly put. Is it justified, the argument goes, to think of genes as fully separable units within the chromosomes, like peas in a pod, or should we conceive of them as integrated parts of much larger chromosomal units? The chemist knows that certain properties of a molecule are dependent upon the existence of a certain atomic group in one region, and other properties on the existence of another atomic configuration at some other position of the molecule. It would be mistaken to ascribe these properties exclusively to the atomic groups involved. These groups are functional as parts of the whole molecule only, and changes either in the groups considered or in other atomic groups of the molecule may result in similarly changed chemical properties. Similarly, it is reasoned, the discovery that specific functions of an organism are controlled by localized spots in the chromosomes does not necessarily mean that these spots, the genes, are independent molecular units. Whatever the final decision in this question will be, it remains justified to distinguish mutational events of coarse chromosomal nature from changes at a molecular level.

Both types of mutations are the raw material of evolution. This will appear obvious for the qualitative, molecular mutations, but may be surprising for purely quantitative changes in genic number. Why should simple duplication of genic material, or simple loss of it, make for new types of organisms? The answer may be given in terms of a comparison with an orchestra. If the members of the orchestra represent the assemblage of genes, then the sound of the symphony played by them may be compared to the harmony of development controlled by the genes. A change in the score of any player would change the symphonic unit. It would correspond to the effect of genic mutation. In addition, a change in the number of players of a given instrument or of a group of instruments would change the symphonic impression. Similarly a change in the number of genes, without change in their individual action, will change the balance of development and result in a new type of organism.

If the material of evolution is hereditary newness, created by recombination of genic varieties and of quantitative changes in gene numbers and

made possible by the existence of mutations, it still needs to be asked what is the moving force, the cause of occurrence of these mutations. The answer has sometimes been searched for in terms analogous to purposeful human thought. Because organisms are built and function as if a purposeful human mind had devised them—though infinitely more wonderful than any human mind could really have dreamt of—it has been speculated that a special force inside the organisms directed the occurrence of mutations so as to bring about their appearance and their specific type in response to "the needs of Nature." As methodologically doubtful as such views always were, we do not need to challenge them solely on the basis of general considerations. We have evidence for the statement that the cause of mutations may be seen not in the power but in the frailty of matter.

Mutations involving loss or duplication of whole chromosomes or coarse chromosomal parts are visibly the results of accidental breakdowns in those mechanisms which normally serve their orderly distribution. Gene mutations too are due to accident, on the molecular level. Accidental variations in the internal energy distribution of a gene may result in chemical reorganization, and accidental production in the cell of reactive atomic groups near the genes likewise may lead to such changes. "Accidental," of course, is not equivalent to "without causes." Causes not only exist but can sometimes be specified, as when radiation or temperature shock infringe on cells. The essentially accidental aspect of mutation consists in the lack of relation between the functioning of the organism as a whole and the intracellular change. Neither does the state of the organism direct in a specific way the occurrence of mutation, nor do the mutations usually, having occurred, guide the development of the offspring into well-suited new channels. All this is not surprising. When the geneticist recognizes that the material of evolution consists of entities at the molecular level, he must accept the consequence that changes at that level will be related in an indirect way only to the evolution of the organismal superstructure. A break in a peptide bond in a gene molecule or the replacement of a carboxyl group by some other radical may perhaps be dependent on some aspect of the physiological state of the organism, but the dependence seems at best very loose. The consequences of these molecular changes upon the development of an egg in which the changed gene molecule is present are fortuitous, as seen from the aspect of the necessary harmony of the existing species.

The problem of the evolution of ever new harmonious forms is thus different from that of the origin of hereditary newness itself. A hundred years ago this problem was recognized, so clearly, by Charles Darwin. His solution of it has reappeared, only slightly changed, in modern dress. Neo-Darwinism, which is the name for the genetic theory of the means of evolution, bases itself upon the existence of random mutations and analyzes the means of establishing successful genic combinations. This analysis is carried on in various ways by means of theoretical investigations, by observation, and by experimental procedures. Theoretically, it is possible to calculate how the genetic constitution of a population will change, given such factors as mutation, selection for certain gene varieties in preference to others, migration of parts of the population into new habitats or new ecological niches, or by random changes inherent in the fact that an element of pure chance enters into the processes by means of which the various gene varieties present in a group of parents are handed down to their young. Observationally, one may follow the changes which occur in natural populations, as for instance, snails, by taking a census of the frequency of various genetic types, from year to year or over longer periods. Experimentally, one may study over many generations the fate of artificially constructed populations kept in large breeding vessels called "population cages," into which are introduced known mixtures of individuals of different genetic constitutions, for instance of *Drosophila*.

The primary means of evolution as seen in these studies are natural selection and random change. The Darwinian principle of natural selection translated into genetic terms concerns the differential ability of different types to transmit their genic varieties or combinations of varieties to later generations. Sewall Wright, who has been one of the principal creators of the mathematical theories of evolution, has pictured the host of genetic combinations as being distributed over a symbolic landscape of peaks and valleys whose elevations indicate degrees of adaptiveness as measured by reproductive survival values. A species which by recombination of its genic or chromosomal varieties constantly produces new combinations explores, so to say, the field of adaptive peaks and valleys. Natural selection will hold a species on an adaptive peak, once it consists of a majority of individuals with the appropriate constitutions, and it will also guide it to other adaptive peaks if it happens to form new genetic combinations which are suitable for survival under different, usually ecologically different, circumstances. Moreover, the peaks and valleys of the symbolic landscape are not permanent

features. Geologic secular changes in the physical environment as well as changes in the living environment of a given species will make ill-adapted genetic types that were formerly well-adapted, and well-adapted formerly ill-adapted ones. Hills become dales and dales become hills. The task of natural selection thus is never-ending. In this view "progress" in evolution is mostly holding one's own while swimming against the stream!

In addition to natural selection of the random products of mutation and recombination, shifts in the genetic makeup of populations can be caused by nonselective events. If a group of individuals contains two or more varieties of a given gene and if these different varieties are all of equal survival value to the individuals which carry them, then one might not expect a change in the proportions of the varieties from one generation to another. While for instance, a specific A^1A^1 individual may accidentally have more offspring than a specific A^2A^2 individual, another A^1A^1 may have less offspring. So, random inequalities should even themselves out. This qualitative consideration is valid if the population is infinitely large so that the number of relatively infertile A^1A^1 individuals is exactly balanced by an equal number of relatively overfertile ones. No population, however, is infinitely large. In small populations it has been shown that chance can bring about great fluctuations in the proportion of genic varieties from one generation to the next. These fluctuations, due to accidental inequalities in reproduction and survivorship, are called genetic drift. Drift might even lead to complete accidental elimination of genic varieties, changing an A^1A^1, A^1A^2, A^2A^2 mixture of genotypes into one consisting of A^1A^1 or of A^2A^2 only. Genetic drift is a formerly unsuspected source of evolutionary change. It can account for the existence of non-adaptive neutral differences between populations. It might be added that an intense discussion is proceeding at present between students who uphold the importance of random drift and others who, while denying its theoretical possibility, disclaim that there ever exist truly selectively neutral genetic differences. Even should this doubt be justified, drift and natural selection would play simultaneously on the keyboard of evolution.

The picture of the means of evolution which emerges is one of an interrelated group of agents all of which may contribute to a shift from one genetic type present in the great majority of the individuals of a population to another. If most members originally could be given the formula $A^1A^1\ B^1B^1\ C^1C^1$ etc., with only a few A^2, B^2 and C^2 varieties present in some individuals, the various factors discussed above might well result in the establishment of a population of which most members might be $A^2A^2\ B^1B^1\ C^2C^2$ etc. A Species II would then have evolved from Species I.

There is room for differences in emphasis in the genetical theory of evolution. Neo-Darwinists usually stress the fact that most mutations or recombinations which lead to striking newness in form or function are selectively disadvantageous. In order to explain the equally valid fact that evolution does produce striking newness of an adaptive, advantageous nature, resort is made to assuming a gradual accumulation of greater and greater divergence by means of natural selection of many genetic varieties with individually minor effects. A dissenting minority view is held by others, who feel that essential newness in evolution is the result of such types of mutations as happen immediately to produce striking divergence from the original pattern of the species. What is a monstrosity as measured by the standard of the existing species may contain the hopeful element of becoming established, as a species well "pre-adapted" to a new mode of life. On this view the attainment of new adaptive peaks may not be the result of slow exploration of the adaptive mountain landscape but of audacious leaps from one peak to another. That the latter method is even more hazardous than the former is obvious, since a random leap from a peak has little prospect to lead to a successful landing on another. Yet, given sufficient numbers of such leaps, one of them may reach a peak which slow exploration might never find.

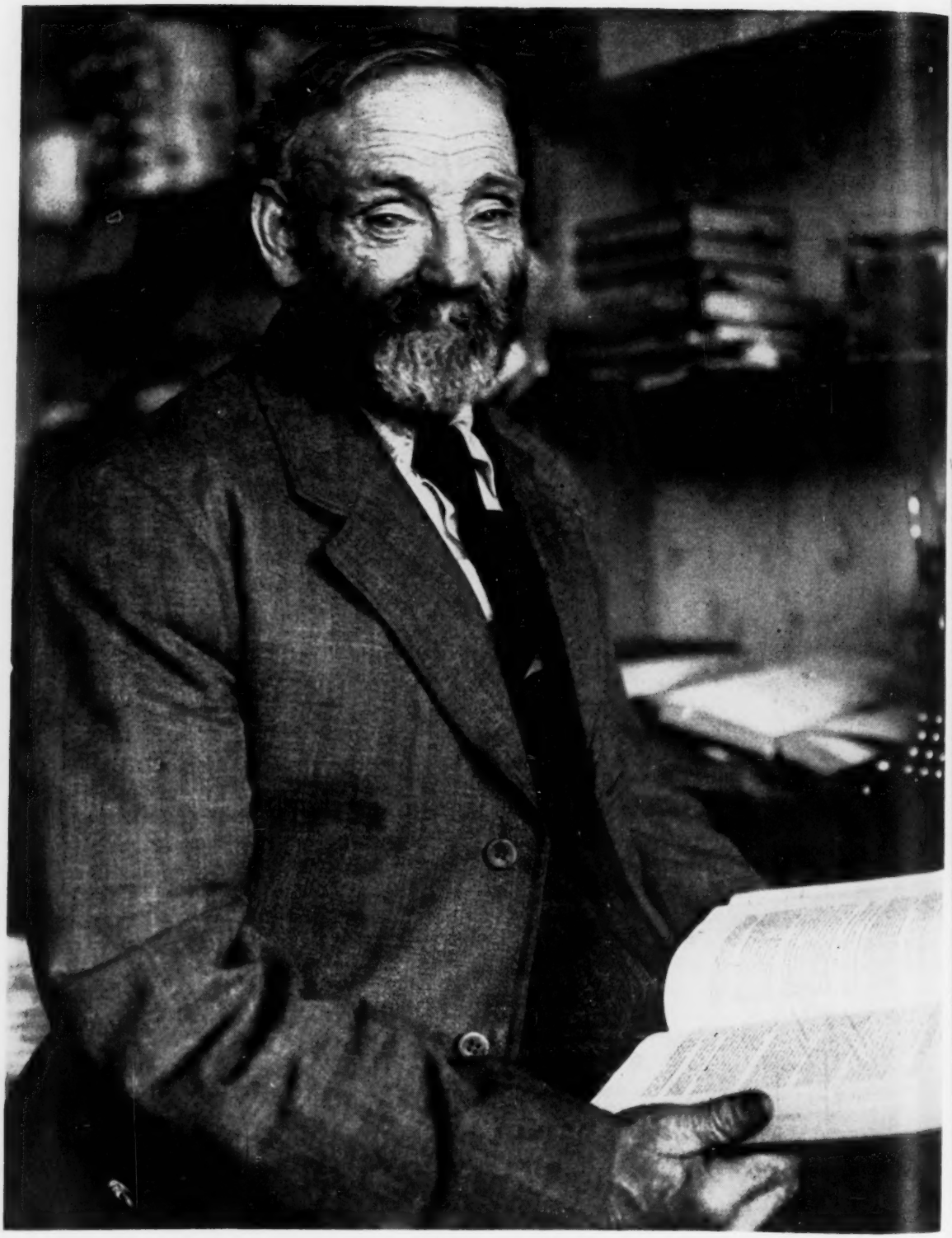
To the geneticist the majestic flow of evolution represents the outward calm of an unceasingly stirring world. Everywhere he discovers chance: chance in the origin of mutations, chance in their consequences upon development, chance in their shuffling into innumerable combinations. Indeed, the realm of chance is awe-inspiring. Granted the origin of life on the earth, the evolution of none of its specific, present or extinct forms seems to have been of a higher necessity. Their peculiar existence, our own existence, is or was accidental. Of the endless number of possible courses which the evolution of life could have taken, the few hundred millions of species which at most originated on our planet bear witness of only an unbelievably limited accidental sample. But perhaps more awe-inspiring yet than the chance aspect of evolution is the fact of evolution itself. Given the existence of matter in its elementary physical form, it was inherent in this matter to compound it-

self into self-reproducing elementary biological units. It was inherent in these genes to be able to elaborate superstructures: unicellular forms and multicellular plants and animals. That these superstructures actually are *Paramecium* and *Chlorella*, oak trees and mushrooms, earthworms and man was among the possible but not deeply necessary events, but that there *would* be evolution into superstructures, that there would be, if you want, successful escape from annihilation into some of the possible channels of change, seems to have been a fundamental endowment.

The geneticist who analyzes the material and the methods of evolution in terms of molecules and of chance is not by that token a callous fellow. To reproach him with lack of religious humility is nothing but a remnant of long worn-out pseudo-religious bigotry. One might wonder whether lack of humility is not present rather in those who try to evaluate the processes of the universe by the limited and changing standards of man's intellect and, shocked by the inapplicability of their standards, want to deny the existence of those processes. The geneticist's probing into the elementary events that underlie evolution opens up vistas into the methods of the world's being and becoming which must impress *all* faculties of the human mind.

OCTOBER

Now the autumn rains begin, and suddenly, where there were none, the fungi rise all through the woods. Not only the familiar stalk and gilled cap of the agaric family, but the brain puff balls, the little earth-measuring stars, sprawling their six points on the ground like black starfish. The old logs burst out with moon growths of white coral; the wet boughs are flecked with delicate tremulas, like shaking bits of dark wine jelly, and around the base of the oaks a great polypore has pushed out, a rich velvety mass of mouse-gray flounces, each ruffle bordered in deep black.—*An Almanac for Moderns.* Donald Culross Peattie, G. P. Putnam's Sons, New York. 1935. p. 219. Copyright G. P. Putnam's Sons, 1935. Reprinted with permission.



Thomas J. Howell taken in 1910 by Huron Smith. (Courtesy U. S. National Museum.)

Thomas J. Howell, Pioneer Oregon Botanist

ERWIN F. LANGE

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ALTHOUGH great quantities of plant specimens were collected by the early scientific expeditions* into the Oregon Country and many publications resulted from these collections, not a single volume dealing with the flora of the great Northwest appeared before 1900. It remained for an amateur in the field of science, an adopted son of Oregon, to complete the first such work. This amateur, Thomas Jefferson Howell, is one of botany's least known investigators. Although a number of brief biographic sketches have appeared, none is complete and none lists all of his contributions to the development of botany in America. This paper summarizes many unpublished facts of Oregon's pioneer botanist.

Thomas Jefferson Howell was born in Cooper County, Missouri, October 8, 1842. He crossed the plains with his family and a group of immigrants. The party left Missouri in April of 1850 and, after six months of slow traveling in two wagons drawn by oxen, arrived in the Willamette Valley in October 1850. The Howells settled at Hillsboro in Washington County.

The next year, in order to take advantage of the then thriving river traffic, the Howell family settled on Sauvies Island twelve miles below Portland at the mouth of the Willamette River, an island visited by nearly all of the early scientific explorers. Two years later the father took on a 240-acre donation land claim and it was here that young Howell, with his two older brothers, John and Joseph, spent many years of his life. Here the Howells farmed and cut down trees to improve the land. At the death of Joseph Howell, also a botanist of considerable note, a Portland paper commented that the Howells "were steady and successful farmers."

* Beginning with Archibald Menzies, 1792; Lewis and Clark, 1805–6; David Douglas, 1825–30; Thomas Nuttall and J. Kirk Townsend, 1833–36; The Wilkes Expedition, 1838–42; and others.

The formal education of Thomas Howell consisted of three months schooling in 1855 in the first school on Sauvies Island. The remainder of his learning consisted of Howell's self-education in reading with the aid of his father. The latter, Benjamin Howell, was well educated and was a medical doctor by profession. His mother was Sarah Rittenhouse of the same family as David Rittenhouse, colonial mathematician and philosopher.

Since childhood young Thomas Howell had an interest in learning about plants. His search for literature to help him in identification of plants proved futile, as there was not a single book describing the flora of the Northwest. He could find plants described only in scattered references. About 1870 he began a systematic study of botany. In 1876 he started collecting and describing specimens. He also began to lose interest in farming.

In 1881, Howell published his first catalog, listing all of the known plants of the great Northwest. In 1887, a second pamphlet, 28 pages in length, entitled, "A Catalogue of the Known Plants of Oregon, Washington, and Idaho," priced at 25 cents, appeared. In the preface he says:

> In 1881 I published (as an advertisement) a list of all the species that I knew had been reported from the territory embraced in the present catalague (sic). At that time I could only find 1844 species and varieteis (sic). The present catalogue contains 2152 species and 227 varieties, 2379 in all; an increase of 535 species and varieties, or about 30 per cent in six years.
>
> No doubt the next six years will show a greater rate of increase, for the Botany of this region is but imperfectly known.

Howell spent the spring and summer of each of these early years searching for new species in the many wild and not easily accessible places of the Northwest. Because of the inadequacy of reference books and materials, the new plants discovered were sent to eastern botanical centers for deter-

mination and identification. The grasses were sent to George Vasey, Department Agrostologist with the United States Department of Agriculture, the sedges to L. H. Bailey at Cornell University, the Gamopetalae to Asa Gray at Harvard, and the Polypetalae to Sereno Watson, also at Harvard University. The botanical literature of the period contains numerous publications by Vasey, Gray, and Watson reporting on Howell's new discoveries. From these references it is possible to list the areas in which Howell collected during the various years. These are:

1879–Columbia River around Hood River
1880–John Day Valley in Eastern Oregon
1881–Southern Oregon
1882–Tillamook, The Dalles in Oregon; Mt. Adams in Washington
1884–Southern Oregon, from Coast Mountains to Siskiyou Mountains, and Northern California.
1885–Eastern Oregon, Wasco County, John Day, and Harney Valley
1887–Southern Oregon, Ashland and Grants Pass
1889–Southern Oregon, Grants Pass

In 1895 he spent two months botanizing off the southern coast of Alaska. Accompanying him on this trip was Martin Gorman of Portland, Howell's good friend and also a well-known amateur botanist.

In addition to the many trips taken during these years, Howell published a number of catalog leaflets (the writer found a number of surplus copies at the Oregon Historical Society library) which were sent to prospective customers. The buyer could check the plant specimens desired and return the leaflet to Howell. The prices quoted varied somewhat during the years, from eight to ten cents each for specimens purchased in small quantities and from four to eight cents per specimen in large orders. This practice was continued until 1896, when the last such catalog leaflet was published.

During the earlier years of Howell's botanical interests he made two of his most important discoveries. The first, made in 1878 jointly with his brother Joseph, was a pond plant growing in his home environment of Sauvies Island. Asa Gray[1] brought lasting fame to the Howell brothers by naming the plant Howellia aquatilia. In reporting the plant, Gray wrote, "It is dedicated to the discoverers who are assiduous collectors and acute observers and who have already much increased the knowledge of the botany of Oregon."

Howell's most important discovery was the weeping spruce, the last of the coast conifers to be found, but it does not bear his name. It was found in June, 1884, at a high elevation in the Siskiyou Mountains on the head waters of the Illinois River in northern California. The tree was named *Picea breweriana* by Sereno Watson[2] who said regarding the name:

The specific name is given in compliment to Prof. W. H. Brewer, who in connection with the California State Geology Survey had so much to do with the botany of the state, both in the field and in the after disposal of the collections of the survey. As he took especial interest in the trees of the coast, and collected a large amount of material for their study, it is fitting thus to connect his name with the forest trees of California.

Travel in the Northwest was difficult during Howell's time and many hardships were endured during the lonely journeys in the often rough, out of the way places. The best extant description of two trips is found in the unpublished Memoirs of Louis Henderson,[3] a Portland school teacher and later a botanist at the University of Oregon. He describes the journeys with Howell in 1882 as follows:

Thomas Howell, then living at the homestead on Sauvie's Island, just where the Willamette joins the Columbia, was a great friend of mine, and I had visited him frequently, rowing down the river from Portland, staying with him, hunting ducks and geese or studying plants Saturdays and Sundays till it was time for me to row back to Portland for my classes on Mondays. So in 1882, he proposed our taking a trip together in his express wagon, first down to Tillamook Bay, then back and up to Mt Adams. We set out a bright day in June for McMinnville, thence crossed the Coast Range by the old wagon road over the mountains, and camped one night on the Trask. While catching a mess of trout for supper, it was my good fortune to run onto a peculiar Rosaceous plant about 2 feet high. I took it back to Howell to see whether he knew it, as he had collected in the Coast Mountains far more than had I, and consequently was more acquainted with the flora. This was the first time he had seen it, so we collected it in quantity. Later we sent it on to Drs. Gray and Watson, and the latter named it FILIPENDULA OCCIDENTALIS. By many this genus has been reduced to SPIRAEA, but FILIPENDULA holds the field again. The next day we were soon in the town of Tillamook, consisting of but few houses at that date. We left our team of horses and wagon at a livery stable, hired a row-boat, and were soon rowing down to the spit, where now is Bay Ocean; but at that early day there was not, as I remember it, a single habitation showing from the water on the whole bay, save a little hamlet or a very few houses at Garibaldi. We went into camp just above high tide, and soon found that the "fly in our ointment" was to be on the one hand mosquitoes, on the other lack of good water. The first we had to endure day and night; the second we overcame by digging with our spade a hole in the sand close up to the spruces, where moist sand alone showed the presence of underground water. Here we lived for 2 days, literally *combing* the dunes, tide-lands, and even shallows for specimens. Most of the plants we gathered were already known to the books, but a few were new species, as we afterwards found out. Among these were the grasses *Poa macrantha* and *Poa confinis*, both named by Vasey, and *Sanicula howellii*, of Coulter and Rose. At the end of our two days, wishing for a good meal of rock-oysters, for which we had heard Garibaldi was noted, we

broke camp and rowed across the outlet to the bay. Very foolishly we took a strong ebb-tide, and only by most vigorous rowing did we escape being carried out to sea. After dinner we waited for an in-coming tide, and made our way back to Tillamook. The row back, as well as out, though long, was hardly tiresome, so busy were we in noting the bird life. In fact, at this early day, our advancing boat was always heralded by flocks of ducks which rose in front of us, circled and then dropped just back of us. The whole surface of the bay was almost covered by these hordes of ducks of dozens of species. We returned to Sauvie's Island to dry out and deposit our large collections, and then proceeded up the Columbia, mainly by wagon over the old road, and finally reached the ferry at Hood River. Near the great rockslide we discovered on the rocks that peculiar, light-colored grass, known as CALAMAGROSTIS HOWELLII, and named by Vasey. The next day we were across the Columbia and on the way to Camas Prairie. On reaching the north end of the valley, we turned westwardly towards Mt. Adams, expecting to find the "good road" for our team and wagon, about which we had been so repeatedly informed since leaving White Salmon. While the yellow pine woods lasted, all went well, the trail forcing us only occasionally to go around some fallen tree, which was easily accomplished in those open, grassy woods. As we ascended the mountain higher and higher, the pine woods gave out, while fir, white pine and mountain or black hemlock took their places. More and larger trees were now across the trail. At first we tried to go around these, but the brush becoming at times impenetrable, we became exasperated by the delays, and finally Howell himself made a most surprising proposition. It was that we both get out and walk, he driving the team and I catching hold of a wheel and helping team and wagon *over the logs!* As the wagon itself was comparatively new and well-made we thought we ran little risk of breaking it to pieces, especially as our load was almost of no weight. So we proceeded for several miles, he whipping up the team as we came to a log, which was practically every minute or two, the horses jumping the log with their front legs, then yanking over the front wheels as they cleared the log with their hind legs, and then, with bumping and crashing, pulled over the back wheels, I all the time assisting with arms and shoulders to keep the team going. This we found was the main point, for if they halted when only the front wheels were over, it was almost impossible to get the hind wheels to follow, if the log was several feet through, as many of them were. Thus, by very exhaustive work, we were able to reach the snow line and a most beautiful camping spot by night. And the glory of those subalpine and alpine slopes of Mt. Adams at that early period (sic). Stock, especially sheep, had not ruined the native pasture at that time, and there were succulent bunch and other grasses up to your knees. Now these grasses have largely vanished under over-pasturing, and often you can barely find any sustenance for your horses if you wish to camp there. Probably the most beautiful and succulent of these grasses is FESTUCA VIRIDULA, then a new species and found by us for the first time on Mt. Adams, though Suksdorf, who was up there at the same time with a band of sheep, first sent it to Vasey. This grass and some of the other bunch-fescues and Poas were then so abundant on the open slopes, that a horse when picketed amongst them by a 40-foot rope would eat his fill and lie down without finishing his forage within the radius of his rope. Now one has often to travel miles before he will see a stalk of these grasses and then only when protected by rocks or brush. On this same trip we likewise found the then unpublished prickly Gooseberry, named RIBES AMBIGUUM by Watson, but later changed to RIBES WATSONIANUM. Here we camped for nearly a week, sometimes working together, and as often solitary on our tramps. Many of the plants were old friends I had seen in '78 and '79, but most of them, on account of later season, were new to both of us, and hundreds of plants were added to our collections. As Thomas Howell was supporting himself almost wholly by the sale of his collections, while I had my regular teacher's salary, I always allowed *him* to send off what collections went East for naming, as anything new, or even rare, brought the most money in the plant market.

The published papers of Howell were confined to two western periodicals, *Erythia*, published by Willis Jepson at the University of California, and the *Mazama*, published by the Mazamas, a Portland mountaineering club. In both instances, Howell had the honor of making a contribution to volume one of the respective publication. However, the paper which received the greatest attention was "The Flora of Mount Hood," appearing in volume one, number one (1896), of the *Mazama* magazine. This article was primarily a list of some 272 species of plants growing in the Mount Hood area above the altitude of 2000 feet. The article had long been forgotten when it appeared in Senate Document number sixteen of the second session of the Seventy-first United States Congress. This document, entitled "Public Values of the Mount Hood Area," was prepared by a special committee appointed by the Secretary of Agriculture to make a study of the features of major public importance in the Mount Hood area and was presented June 9, 1930, by the late Senator Charles McNary of Oregon. Howell's article was included in the appendix with the comment that the list, though incomplete, was the only one available.

Howell's main objective over the years was to compile all of the information regarding Northwest plants into a single, usable flora. The actual writing of this began in 1882 and was completed in 1896. As the time for publication arrived, a new obstacle presented itself; the printers in Portland were unable to set the type because of so many technical words; however, Howell was not to be discouraged. He carefully learned to set type with his own hands; then at his home, he laboriously set eight pages at a time, after which he took them to Portland to be printed. Both the writing and typesetting were difficult for one with only three months of formal schooling. Again, his good friend Martin Gorman helped by correcting copy and reading proofs. Extant letters of Howell's on file in libraries abound in errors, and several of his contemporaries

Brewers weeping spruce. Gold Basin Range, Siskiyou National Forest. (U. S. Forest Service.)

commented on his errors and poor handwriting. Martin Gorman commented that Howell improved considerably by writing his account of the Northwest flora.

On March 15, 1897, the first fascicle of 112 pages appeared under a paper cover, priced at fifty cents. After examining this first fascicle, Willis Jepson[4] wrote a rather lengthy review in his magazine *Erythia*. After noting some minor errors and discussing a few species, he praised the work by saying:

> It is evident from a perusal of the pages that Mr. Howell's work is cyclopedic rather than critical. What he has done has been to bring together in usable form, in the light of his field knowledge (and no other botanist knows so well the plants of these states) all that has been published concerning the flora of the region. But it should, of course, be added that very many diagnoses are his in whole or in part, and that his personal observations color the completed product. Even so much is a task of no small magnitude. The author has not spoken of difficulties, but difficulties must have been many in a region in which library and herbarium facilities are meager. Mr. Howell, therefore, deserves no small meed of praise for the courage and resolution necessary in the face of such circumstances, and we trust that he may finish his volume within the limit of the period contemplated—that is, by the end of the present year.

However, the book was not to be completed during the year. Six and a half years after the first fascicle was completed, the work finally made its appearance under one cover, after seven separate fascicles had been published, each selling for fifty cents. In 1902 Howell wrote in a letter that he was spending eighteen hours a day in an effort to complete his book.

The completed book, *A Flora of Northwest America*, was described as an octavo volume of 792 pages, plus 24 pages of index. About a million words were required to describe 3150 different species, of which 89 were new to science. An original literature reference was included for almost every species. The volume was priced at five dollars but was a financial failure for the author. Today the book is so rare that to find one for sale at five dollars would be almost a miracle; one copy is reported as having sold for $37.50. While rare on the book market, the "Flora" is widely distributed in the libraries of the large universities, and many libraries in Oregon have one or more copies.

After publication, Howell's "Flora" drew attention in various quarters. The *Botanical Gazette*[5] commented:

> Howell's Flora of Northwest America, which has been in course of publication since 1897 is now completed. The author has struggled against difficulties in producing this work, for which he himself has set the type. Those who have used the parts in the field have found it exceedingly useful.

At the meeting of the Torrey Botanical Club, April 12, 1904, Dr. P. A. Rydberg presented a paper on "The Flora of Northwest America," the review of which appeared in *Torreya*. Dr. Rydberg[6] commented on some errors and then, referring to the work, wrote:

> Only those who have been actively engaged in writing manuals of systematic botany can imagine what such an undertaking means, what difficulties are met with and what an amount of work is needed. If the fact is taken into consideration that Mr. Howell had to work far away from libraries with scarcely any other facilities than those afforded by his private library and collection the excellence of the work is really surprising.

The Portland *Oregonian*[7] in a feature article finished concerning Howell's "Flora":

> . . . [that it] is not only a monument to the scientific knowledge and patient industry of the author, but a credit

to the State of Oregon as well. . . . Mr. Howell had all the patience and perseverance necessary to sustain him through these long-continued and unremitting labors and hardships without once faltering in his design, and it must be remembered that it was purely a labor of love, without hope of remuneration at the end worth considering.

Some years later, in writing Howell's life for the *Dictionary of American Biography*, Jepson[8] wrote regarding the first Northwest flora:

Although thus handicapped, he had a sound and just comprehension of what was needed, and he organized diagnosis of genera and species scattered in the works of many writers into a pioneer flora, which considering the circumstances of its production is balanced, judicious, and highly useful. Even after more than a quarter of a century it remains the only flora for the three states which it covers.

After the writing of the "Flora" had been completed and the publication of the book was drawing to completion, Howell decided to give his large collection of plant specimens to the University of Oregon. In a report to the board of regents for January 20, 1903, P. L. Campbell, president of the University, requested that $500 be paid Howell for the job of arranging and classifying the collection. That fall, Thomas Howell was listed as a collector in the department of botany, among the faculty listings in the school catalog. R. S. Bean, president of the board of regents of the University, in his biennial report for 1903 and 1904 to the governor of Oregon and the twenty-third legislative assembly (1905), wrote concerning the collection:

The most notable acquisition by the University during the year has been the invaluable collection of type specimens of the flora of Oregon contributed by Thomas Howell. The great value of this collection, the best certainly in the Northwest, will become more and more fully recognized as time goes on.

Each year since 1904, as a new University of Oregon catalog appeared, the name of Howell has been perepetuated by recognizing his gift of 10,000 specimens to the University's herbarium.

Not only does the University of Oregon possess specimens by Howell, but large numbers are to be found in herbaria over the entire United States. Between 2200 and 2300 specimens are deposited in the Chicago Natural History Museum and large numbers are in such centers as the United States National Herbarium, the Gray Herbarium at Harvard University, The Britton Herbarium of the New York Botanical Garden, the Jepson Herbarium of the University of California, and undoubtedly others.

All who knew Howell spoke of his poverty. At least two botanists of note came to Portland to talk and visit with Howell. In 1906, Willis Jepson came to Portland and rode for forty minutes on the electric interurban trolley toward Oregon City to the place where Howell was building a house in a new clearing. Of his poverty, Jepson[9] wrote in his field book:

It is too bad to see him [Howell] so miserably poor. He came into Portland with me and I insisted on his taking lunch with me but he would allow only a few simple things to be ordered for him.

Martin Gorman reported to Jepson[9] that his poverty was due to:

. . . [his having] lost the money from the sale of his share of his father's estate in unfortunate investments. One man promised him an income of $300 a year, $25 a month, if he would put in $3000. Mr. Howell felt that he could live on $25 a month in a simple way and work on his flora. But he never got back a cent on either interest or principal. Another man who was looking for suckers got him into a laundry business scheme, and in addition got his signature to certain notes for machinery and then skipped out.

In October, 1910 Huron H. Smith, Dendrologist of the Field Museum of Natural History of Chicago, made a special trip to Portland in order to spend a day with Howell. At that time Howell was living on Hood Street in Portland where he had a small grocery-confectionary store, which was also his residence. Smith[10] reported on Howell's limited finances and said that Howell was spending his time making coarse teamsters' mittens on a sewing machine for seven cents a pair. However, in spite of his poverty he was "very cheerful at all times and betrayed no impatience with depressing external conditions."

During the early years of Howell's interest in botany he lived on the old homestead on Sauvies Island and engaged in farming with his two brothers. From February, 1873 to August, 1876 he served as postmaster of the Willamette Slough Post Office on Sauvies Island. The name of this post office was later changed to Arthur, Oregon, and this address appeared on Howell's catalogs until 1894. After 1895 his catalogs were issued from Clackamas, Oregon. From December, 1904 to March, 1906 he again served as postmaster, this time of the Creighton Post Office, which is today the Oak Grove Post Office. During the intervening years he operated grocery stores in Clackamas, Milwaukie, and finally on Hood Street in Portland.

Howell was married in 1892, at the age of 50, to Effie Hudson. They had two sons. Jepson,[9] after visiting with Howell, described him as "a man below medium height, his hair brown and gray, shortish full beard, reddish face, blue eyes, slightly Roman Nose."

Thomas Howell died December 12, 1912, after a long illness and only two months after the death of

his older brother Joseph, also a contributor to the knowledge of Northwestern botany. In writing his obituary, a contemporary botanist, Edward L. Greene,[11] who has also reported some of Howell's discoveries, extended him the highest tribute in these words:

> That which is most peculiar and noteworthy about Mr. Howell's career is, that he accomplished the greatest amount of meritorious and valuable scientific work that was ever done by any man of any epoch, on so very rudimentary an education in letters.

And Jepson[8] wrote of Howell:

> Few men leaving a durable contribution to American botany have led so obscure an existence as did Howell.

While the great names in American botany are memorialized by having botanical clubs, periodicals, and herbaria named after them, Thomas J. Howell, uneducated and not affiliated with a large university, is almost forgotten except by botanists and the botany students who find his "Flora" on a library shelf or who are impressed by the 30 Northwest species and varieties bearing the name *howellii*.

Thomas Howell's Publications:

1. Catalogue of the Flora of Oregon, Washington, and Idaho (1881).
2. A Catalogue of the Known Plants of Oregon, Wash- ington, and Idaho (1887).
3. A Rearrangement of American Portluceae. *Erythia* **1,** 29 (1893).
4. New Plants of Pacific Coast. *Erythia,* **1,** 109 (1893).
5. Note on Sedum Radiatum. *Erythia,* **1,** 144 (1893).
6. New Species of Pacific Coast Plants. *Erythia* 3, 3 (1895).
7. Distribution of Darlingtonia in Oregon. *Erythia,* 3 179 (1895).
8. The Flora of Mt. Hood. *Mazama,* **1,** 28 (1895).
9. The Flora of Mt. Adams. (Co-author, William N Suksdorf). *Mazama,* **1,** 68 (1895).
10. *A Flora of Northwest America.* Portland, Oregon Aug. 10 (1903).

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Circulatory Adaptations to Birth

S. R. M. REYNOLDS

Dr. Reynolds received his A.B. and M.A. at Swarthmore College, and his Ph.D. at the University of Pennsylvania. He has taught physiology at Western Reserve University and at the Long Island College of Medicine. In 1941, he joined the Department of Embryology, Carnegie Institution of Washington. He has held two Guggenheim Fellowships. Much of the work on which the following article is based was done during his second fellowship, when he worked at the Nuffield Institute for Medical Research, Oxford University.

AT the moment of birth, a series of related and interdependent changes takes place in the circulatory system of the fetus. This is necessarily so, since the requirements of the fetus demand one set of specialized circulatory conditions and those of the newborn infant require another, very different, set of conditions. Nature usually contrives to achieve a normal and orderly change from one to the other. The mystery of the mechanism of vascular adjustment deepens and the wonder grows as one contemplates the complex but orderly changes that make possible the abrupt transition from a dependent life in a fluid medium within the womb to an independent life in an environment of air.

The basic anatomical differences between life in the two conditions have been known since the days of William Harvey in 1628, although anatomists of an earlier time, extending back to the days of Galen in the second century A.D., knew of one or another of the essential differences.[1] In terms of development, the fetus is an aquatic organism, deriving its oxygen and sustenance from maternal blood and giving off its waste products to it, across the tissues and structure of the placenta. The newborn infant, like the older adult, derives its oxygen through its lungs and gives off its waste carbon dioxide across the tissues of the pulmonary barrier. The change in mode of respiration depends upon extensive alteration in the course of blood flow throughout the organism. The nature of this change-over has been established only recently. What is the basis of these adjustments?

The heart receives blood through the large veins that enter it and distributes blood to the arterial system. In both the fetus and newborn, blood enters the heart by way of the right auricle (a word meaning "ear"), or the first chamber of the heart. After birth, blood passes from the right auricle into the right ventricle ("little belly") and thence into arteries that carry it to the lungs, where the respiratory exchange of gases is effected. The oxygenated blood then returns through veins to the left auricle of the heart and thence to the left ventricle, from which it is sent through the branching arterial system to all parts of the body.

In the fetus, the blood that flows in the veins coming from the lower parts of the body is in large part composed of oxygenated blood that has entered the body of the fetus through the umbilical vein. Hence it is the "best" blood in the fetal body. Reaching the heart, it passes in one of two directions. The blood that strikes one side of a recently

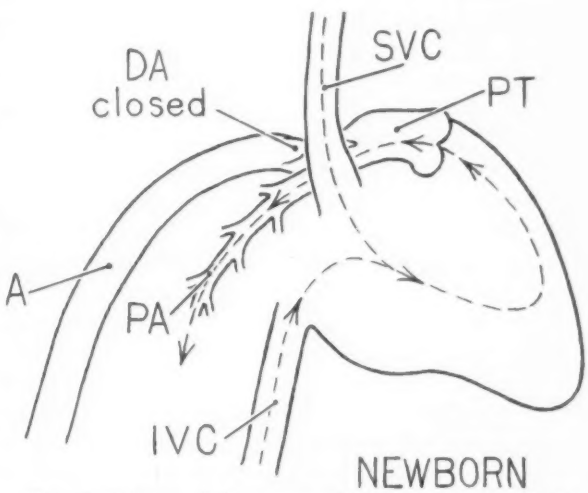

FIG. 1. Scheme of the course of blood flow through the postnatal heart. Venous blood from the superior vena cava (SVC) and inferior vena cava (IVC) enters the right side of the heart. The right ventricle ejects it into the pulmonary trunk (PT), from which it goes to the lungs by way of the pulmonary arteries. Not shown is the return of blood from the lungs to the left side of the heart and thence into the aorta.

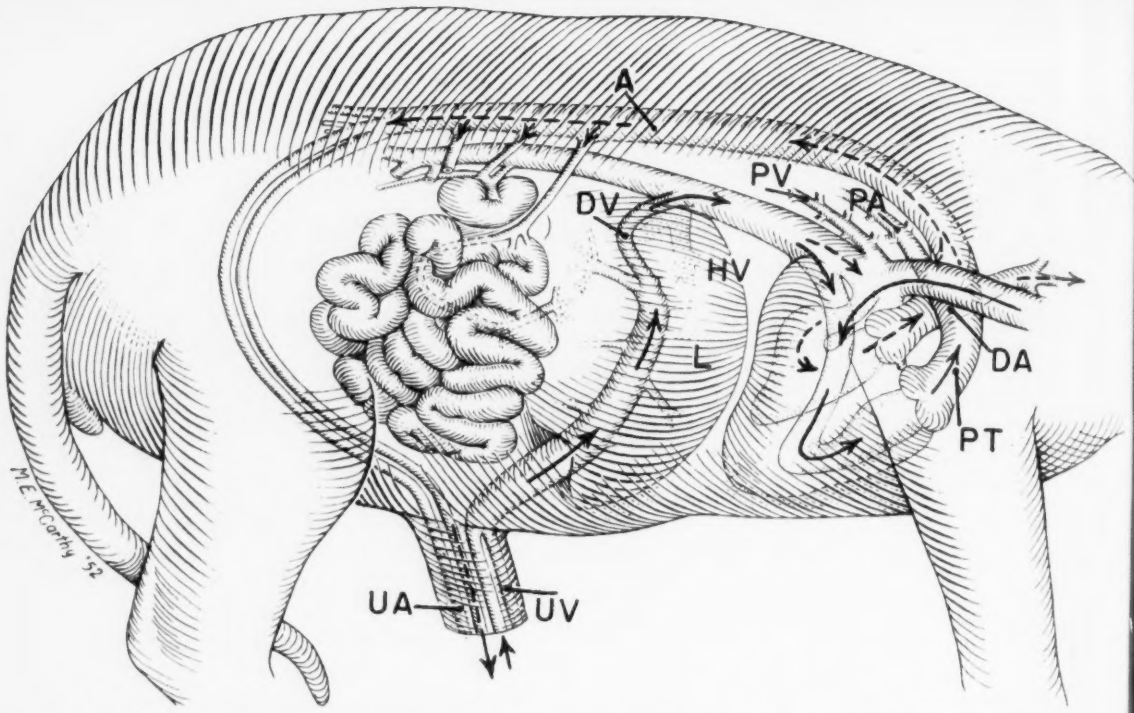

FIG. 2. Schematic diagrams of the course of the circulation of blood in the fetal lamb. Blood, oxygenated, enters the body in the umbilical vein (UV) and goes to the liver (L). It continues through the liver to the heart (shown enlarged at the right of the chest) by either of two channels: (a) by a direct connection, the ductus venosus (DV) or (b) an indirect route, through the hepatic veins (HV). At the heart, the blood stream divides. Part of it goes to the right side of the heart, to leave by way of the pulmonary arterial trunk (PT). The blood stream enters either the arteries going to the lungs or the ductus arteriosus (DA), a connection between the pulmonary vessel and the aorta (A), the large systemic vessel along the back. Thence the blood is carried to organs of the abdomen, the lower part of the body, and the placenta via the umbilical arteries (UA). The blood that goes to the left side of the heart leaves by way of the aorta and passes to the head as well as to the lower parts of the body. Pulmonary artery (PA) and pulmonary vein (PV) carry little blood in the fetus.

recognized promontory of tissue, the crista dividens ("dividing crest"), passes, along with blood from the head end of the body, into the right auricle and thence to the right ventricle. The blood that strikes the other side of the dividing crest passes through an opening, the foramen ovale ("ovai opening"), in the septum or wall of tissue between the right and left auricles, and enters the left auricle. This blood passes in turn to the left ventricle, hence having by-passed the right side of the heart.

Before birth, the blood that enters the ventricles of the heart leaves by way of the arteries leading from them, namely, by way of the pulmonary arterial trunk from the right ventricle, and by way of the aorta, from the left ventricle. This is also true in both the newborn and the adult organism. However, a second difference between the two types of circulations lies just beyond this point. About an inch from where the main pulmonary arterial trunk begins, it divides into three branches. The two smaller branches go to the lungs, one to the right and one to the left. Lying more or less between these two branches, the main pathway continues, for a short distance, to join the large aorta arising from the left ventricle of the heart. Here, then, is a direct and major connection between the two great arterial systems of the fetus. This connection is known to anatomists as the ductus arteriosus. Only a relatively small quantity of blood finds its way into the nonfunctioning lungs of the fetus from the pulmonary artery, instead of going into the ductus arteriosus; this returns to the heart through the pulmonary veins. It enters the left auricle where it joined by the blood coming through the foramen ovale that connects the two auricles, as mentioned above, it passes into the left ventricle, to be discharged into the aorta.

In infants and adults, the two arterial systems that arise from the right and left sides of the heart, respectively, are quite separate. Prior to, and until the moment of birth, however, they are connected by the ductus arteriosus; thus a large portion of the blood that leaves the right ventricle joins that coming from the left ventricle. This mixed stream passes to the lowermost regions of the body, where it supplies the abdominal organs and the legs. Mainly

however, it goes to the placenta through two large arteries that pass from the lower part of the aorta into the umbilical cord. The main purpose of this part of the circulation is to assure the fetus an abundant and continuous circulation of its blood through the placenta where, in fetal life, the vital processes of respiration, assimilation, and excretion take place.

The cardinal structural differences between the fetal and newborn circulations are now clear. They are basically three in number: (1) the abundant and important placental circulation in the fetus; (2) the crossover in the fetus, by way of the foramen ovale, of blood between the two auricles or receiving chambers of the heart, and (3) the shunt by way of the ductus arteriosus between the two arterial systems, which arise respectively from the two sides of the heart. At the moment of birth, each of these structures—placenta, foramen ovale, ductus arteriosus—becomes nonfunctional; and from that time on the newborn organism normally breathes in the adult fashion, with all that this entails in readjustment of the vascular system to the altered conditions of life. These are structural and functional changes that must, and do, occur with remarkable rapidity.

Before consideration of the timing and cause of the change-over from the fetal to the newborn condition, two points should be mentioned in passing. First, for what purpose, the reader may ask, does some of the blood freshly charged with oxygen in the placenta return to the heart and pass through the foramen ovale into the left side of the heart? We saw above that all of the blood remaining on the right side of the heart goes to the lower part of the organism, particularly to the placenta. The blood from the left side of the heart enters the aorta on its way to meet the stream of blood coming through the ductus arteriosus from the right side of the heart. On its way, some of the blood leaves the aorta by appropriate arterial branches to go to the developing brain, the head, and the remaining forepart of the animal. Since these are the first branches to leave the aorta, above the point where it is joined by the ductus arteriosus, the crossover of blood between the auricles in the heart assures that the brain in particular will receive, almost directly, blood that is rich in oxygen and nutrient substances and low in the waste gas, carbon dioxide. A more efficient arrangement can hardly be imagined.

The second point to consider is concerned with the character of blood flow from the placenta to the heart. As the blood moves in great volume and at an appreciable velocity through the umbilical vein, it reaches the fetal liver. Here, the blood returns by two paths to the large vein, the inferior vena cava, in which it is carried to the heart: it may go by an indirect route through the blood channels of the liver and thence by way of veins draining the liver to the inferior vena cava, or it may go by means of a direct connection (another shunt, termed ductus venosus) from the umbilical vein to the inferior vena cava and so to the heart.[2]

The course that the blood takes in traversing this part of the vascular system is governed by a muscular mechanism that can open or close and which is located at the begining of the ductus venosus. When it is open, little blood goes by way of the liver; when it is closed, all the blood goes by way of the liver. The purpose served by such a mechanism of control remains to be discovered. As of today, one can say that the controlling sphincter muscle seems to be sensitive to fluctuations in blood pressure within the umbilical vein, and closes when a large volume of blood rushes back from the placenta as it does when the maternal uterus contracts. Closure of the ductus venosus diverts blood into the liver, which therefore acts temporarily as a reservoir to store the excess quantity of blood and so to prevent overloading, and perhaps embarrassment, of the fetal heart.

Whatever the purpose and exact character of this elaborate mechanism ultimately may be found to be, it ceases to exist after the organism is born. It, like the other three mechanisms mentioned above, has fulfilled its purpose at birth, and so it disappears with the beginning of that life which depends upon ventilation of the lungs. These are indispensable mechanisms during fetal life, but necessarily dispensable immediately afterward.

The nature of the anatomical change-over at birth that is associated with the circulation of blood, is now clear. The pathways of the blood flow in the fetus are also evident, and accepted by students of the subject. However, the acceptance of these facts had to await their clear demonstration in 1945 by a group of investigators at the Nuffield Institute for Medical Research, Oxford, England. In that year, A. E. Barclay, K. J. Franklin, and M. M. L. Prichard published their now classic monograph on the fetal circulation.[1] In it they presented the proof that established the pattern of blood flow which can now be stated with the certainty outlined above. This was a noteworthy advance in our understanding of life processes; it seemed then that little else could be added to our understanding of the subject. Nevertheless, crucial questions remained unanswered. Why, for example, do the ductus arteriosus and foramen ovale close? When do they close? At once, with onset of breathing, or after some delay? Together, or singly?

In 1951, in the course of other studies at the Nuffield Institute for Medical Research, using fetal

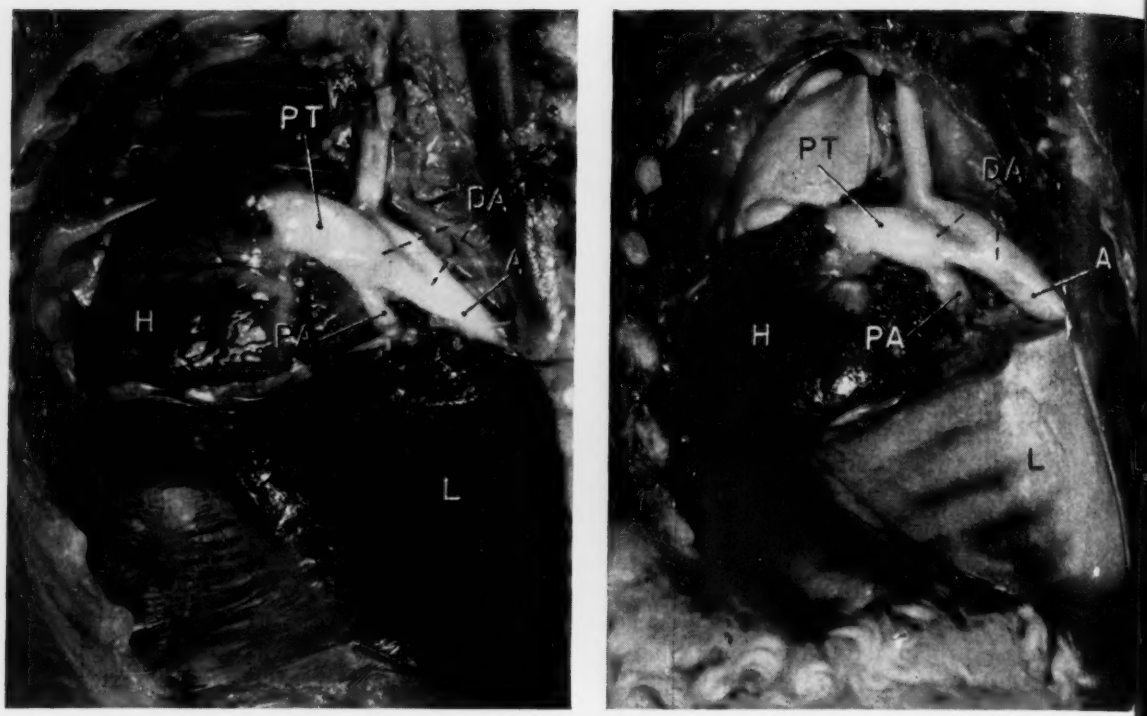

FIG. 3. Two pictures of the ductus arteriosus. Left, from the fetal (nonbreathing) lamb; right, from the newborn (breathing) lamb. The ductus arteriosus (DA) is open on the left, constricted on the right. Other labeled structures are the heart (H), the lung (L), the pulmonary artery (PA) and pulmonary arterial trunk (PT), and the aorta (A). The ductus arteriosus connects the two latter. (From *The Foetal Circulation,* by Barclay, Franklin, and Prichard.)

lambs, these and other theretofore unthought of questions were answered. The answers revealed a beautifully timed and integrated group of circulatory adaptive mechanisms associated with birth. These involve changes in blood pressure and the rerouting of blood flow throughout the organism. The trigger for the complex group of mechanisms is inflation of the lungs and a change in the amount and character of the blood flowing through them.

These new observations could be made in 1951 and not in 1945 because of a radical improvement in the method of photographing the fetal circulation. In the earlier work, cineradiographs, or x-ray movies, were taken at a frequency of three to six pictures a second. This was too slow to permit them to be viewed as regular moving pictures. In the later work, Dr. G. M. Ardran arranged to take pictures at a rate of twenty-five frames a second, a speed well-suited to studying the movements of blood throughout the organism. Blood pressure was also recorded.

In the fetus, as noted above, blood flows from the pulmonary arterial trunk to the aorta through the ductus arteriosus. One may assume, therefore, that the blood pressure in the pulmonary trunk is higher than in the aorta, into which the blood flows. In the adult organism, i.e., in the absence of the ductus arteriosus, pulmonary arterial blood pressure has long been known to be very much less than aortic blood pressure. Presumably this change takes place at birth or shortly afterwards.

Attempts to measure the changes associated with onset of respiration by W. F. Hamilton, R. A. Woodbury, and E. B. Woods at the University of Georgia in 1937, failed to reveal the course of such changes of blood pressure, as did earlier observations of the German workers, J. Cohnstein and Zuntz, in 1884 and 1888. One worker, B. S. Schulze, in 1871 suggested, without proof to support his contention, that an increased vascular capacity of the lungs with aeration, coupled with closure of the ductus arteriosus, would cause a fall in systemic blood pressure, prior to its subsequent rise. This, as we shall see, so clearly presages the recently made observations that it is regrettable that Schulze cannot have the satisfaction of seeing how men whom he never knew are today "marching to the measure of this thought."

Throughout the intervening period, from 187[illegible] until the present day, stress has been laid almost exclusively upon the cause and effect of closure of the ductus arteriosus in the circulatory adjust-

ments to postnatal life. That this adjustment would be secondary to another one seemed unlikely, since the position of the ductus arteriosus was so prominent and since it is so unique a structure in the fetus. We now can put closure of the ductus arteriosus in perspective against the total complex of changes taking place at birth. Let us see why this is so.

A new group of workers were associated during 1951 in a reinvestigation of this problem at the Nuffield Institute in Oxford, England. The radiologist, Dr. G. M. Ardran, a physicist, Mr. D. G. Wyatt, and physiologists, including Drs. G. S. Dawes, M. M. L. Prichard, and the present writer, combined to make a team.[3] Experiments were carried out on fetal lambs delivered from anesthetized ewes near term. Breathing was prevented by applying a fluid-filled rubber bag over the nose, and allowing the lamb, also anesthetized, to remain attached by its umbilical cord to the placenta which was still in place within the womb.

In this way, it was possible to work on the lamb as it remained in an essentially fetal condition. Blood pressure was recorded at each end of the ductus arteriosus, by means of small cannulas thrust through the pulmonary trunk and aorta and connected to capacitance manometers. The flow of blood was recorded by taking x-ray moving pictures of the entire fetus at a rate of twenty-five pictures

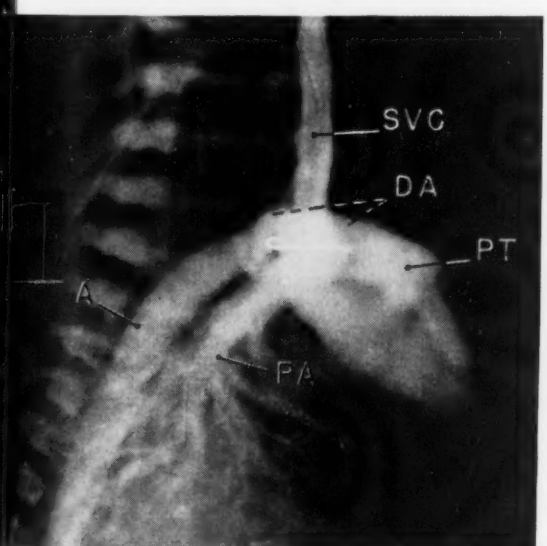

FIG. 4. Path of contrast medium injected from the head end of a fetus shown in a cineradiograph. A wire had been sewn on the ductus arteriosus. The contrast medium passed through the superior caval vein (SVC) entering, only the right side of the heart. Thence it went to the pulmonary trunk (PT), through the ductus arteriosus (DA) and into the descending aorta (A). Some also passed into the pulmonary artery (PA).

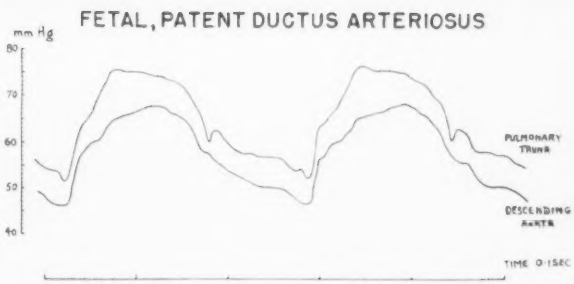

FIG. 5. Two pressure pulsations in the fetal condition, from the fetal heart in the pulmonary arterial trunk (top) and the descending aorta (bottom). The pressure in the former always exceeds that in the latter. (G. M. Ardran, *et al. J. Physiol. London*, 1952.)

per second. A suitable contrast medium was injected in such a way as to display the various parts of the vascular system requiring study, especially the pulmonary arteries and the ductus arteriosus. After observing the blood flow and blood pressure in the lamb in the fetal condition, aeration of the lungs was permitted. At suitable intervals afterward, the pressure and flows were determined, again and again. In this way, comparison of the state of the circulation with the passage of time after the onset of aeration of the lungs could be readily evaluated.

The results were dramatically clear. Prior to aeration of the lungs, the pressure at the beginning of the ductus arteriosus in the pulmonary artery exceeds that in the aorta, at the other end of the ductus arteriosus. The flow of blood through the lungs is very slow and exceedingly small in amount. Therefore, most of the blood from the right side of the heart enters the aorta through the ductus arteriosus, where, in moving pictures of it, one may see the two streams mixing turbulently as the blood rushes along the aorta toward the placenta. This is in the fetal condition.

When ventilation of the lungs begins, there is at once a profound fall in both the pulmonary arterial and aortic blood pressures, just as Schulze predicted in 1871. The fall in blood pressure coincides with and depends upon an enormous increase in the velocity and volume of blood flow into the lungs as the minute blood vessels of the lungs expand and fill with blood. The faster flow into the lungs at a lower pressure obviously means that the resistance to blood flow in the lungs diminishes upon their aeration. While the blood pours into the lungs, there is a reduction in the return of blood to the heart. This accounts for the fall in blood pressure in the systemic arterial system described above. Inasmuch as the lungs fill up after a few minutes, blood returns to the heart, and so the level of systemic blood pressure recovers. In the pulmonary

system, however, the blood pressure remains low because the originally high resistance to blood flow through the numerous nonexpanded blood vessels of the fetal lung becomes very low upon aeration of the lungs. Consequently, blood rushes through the lungs and back to the left auricle of the heart. This change in resistance to blood flow in the fetal lung was measured in 1952 by Dr. G. S. Dawes and his associates, Dr. J. Widdicombe and Dr. Joan Mott. The changes just described commence with the first filling of the lungs with air, and usually become stabilized within ten to twenty minutes.

What happens to the ductus arteriosus at the time when these crucial changes take place? At what time does it close? Cineradiographs show that it effectively closes within a minute or two after the onset of ventilation of the lungs. It closes when the blood pressures in both arterial systems are at their lowest points. Why should this be so? The answer to this question may be stated today only in hypothetical terms. The best explanation is as follows: normally, the ductus arteriosus, a distended structure containing elastic and muscular tissues, tries to close at all times, but it is held open by the high blood pressure within it. This results from blood being forced through the ductus arteriosus during fetal life, where it is deflected by the high resistance to flow in the lungs. With aeration of the lungs, resistance to blood flow decreases, as described above, and in consequence blood is diverted from the ductus arteriosus. Then, as the force of blood pressure restraining closure of the ductus arteriosus in the fetus lessens, the ductus arteriosus is able to close. This may be called a hemodynamic theory of closure of the ductus arteriosus.

In support of the above view is the fact that when a state of asphyxia is transiently induced while the lamb is in the fetal condition, this is accompanied by a generalized constriction of blood vessels and a rise of blood pressure.[3] Cineradiographs show that the ductus arteriosus closes, too, as the power of its contractile force overcomes the pressure of blood within it. Recently, the author has likewise observed this directly in anesthetized fetuses with opened chests. The ductus arteriosus visibly and powerfully constricts as asphyxia develops.

The concept of ductus-arteriosus closure just described is a mechanistic one. It is characterized by simplicity. As such, it stands in contrast to the two previous theories that have been propounded and found wanting. One of these is that the ductus arteriosus closes as the result of nervous reflex action associated with distention of the lungs upon

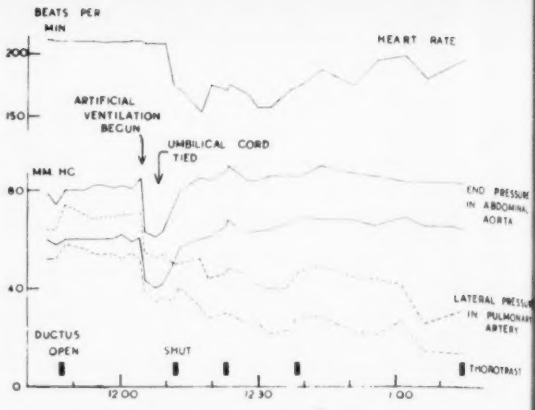

FIG. 6. Effect of breathing on the blood pressure of the fetus. Aortic pressure was recorded from the far end of the aorta, where the pressure reading was higher than a "lateral" pressure reading taken higher up. The effect of ventilation was to cause a transient fall in blood pressure, then a divergence into the condition characterizing the newborn. The ductus arteriosus was found to be closed at the times indicated by the black marks at the bottom, after ventilation of the lung had commenced. (*G. M. Ardran, et al. J. Physiol. London,* 1952.)

inflation. It has been observed, however, that after severing the nerves to the ductus arteriosus, it will close when the lungs are aerated. A nervous reflex mechanism is not essential, therefore. The second theory holds that when air fills the lungs the oxygen in it acts, when transported by the blood stream, as a stimulus for the muscle of the ductus arteriosus to contract and shut. The fact that the ductus arteriosus closes during asphyxia, when oxygen is low, as described above, belies this. Moreover, physiologists know that oxygen does not act as a stimulant to muscular contraction. The hemodynamic theory recounted above has the virtue of simplicity, and it fits the known facts.

Nothing can as yet be said regarding precisely why, when, or how the foramen ovale closes. An anatomical peculiarity of this structure is that a loose, tough membrane overlies it in the left auricle and acts as a flap valve. The supposition is that when the blood flow becomes well established through the lungs after aeration and returns at high velocity to the left auricle, it forces the membrane over the foramen ovale to close. In the case of both this structure and the ductus arteriosus, prolonged closure resulting from the kind of physiological conditions described above permits the growth of new tissue to bring about their permanent anatomical obliteration as structures concerned with the passage of blood. Recent measurements of pressures within the heart affirm the above ideas.

When the cineradiographs obtained in the study at the Nuffield Institute were reviewed, upon completion of the experiments in 1951, a new, dynamic

concept of the fetal circulation was developed. This evolved from the fact that it was possible to calculate the speed of travel of the injected opaque medium used in the x-ray procedures between different parts of the circulation, before and after the onset of breathing. Moreover, in the aorta and umbilical arteries, the velocities as well as the diameters of the vessels could be measured. It became possible, therefore, to compute the volume-flow of blood per minute in these vessels. A very general statement of the results of these observations is of interest, for it shows the beauty that is the wisdom of the body.

In the fetal condition, the circulation times for the flow of blood is quite slow in the forepart of the organism. This includes the lungs and head. In contrast, the fastest flows are found in the aorta and throughout the lowermost part of the animal. When pulmonary respiration is established, however, a reversal takes place. There is approximately a threefold speed-up in the rate of blood flow through the head, and a fivefold increase in flow along the pulmonary arteries. The rate of flow in the aorta diminishes appreciably. In short, in both the fetal and newborn conditions nature provides the fastest flow of blood to the organ that in each instance is concerned with exchange of oxygen and carbon dioxide—the placenta and the lungs, respectively.

It was noted above that the flow of blood to the head of a fetus is so arranged that freshly oxygenated blood returns from the placenta to the heart, where it takes the most direct route possible to the head. We now see that at this time the velocity of flow is slow. There is a compensating factor to the slower velocity, therefore, in the better quality of blood going to the head. This mitigates the fact that the primary organ of respiratory exchange lies at the other end of the body, away from the brain. The placenta demands a more rapid and more abundant circulation of blood.

Long and careful study of the cinefluorographs has made possible the determination of a number of other significant physiological facts concerning the fetal circulation. Of these, four may be mentioned. These are all concerned with the volume of blood flowing to the aorta and umbilical arteries of the fetus. Essential for this determination is the fact that the speed of movement of injected opaque contrast medium had to be clocked as it moved from the heart along the aorta and umbilical arteries. The diameter of the vessels was determinable from the pictures. With these data, the volume of blood flowing per minute could be calculated.[4] Let us look first at the rates of flow of blood in the aorta and umbilical arteries.

In fetal lambs weighing from five pounds to more than eleven pounds, the amount of blood flowing down the aorta varied from about 900 to 3000 cubic centimeters per minute. The largest volumes were in the largest animals. It was unexpected that values so large as this would be observed in such relatively small organisms. In an adult young man at rest, the output of the heart

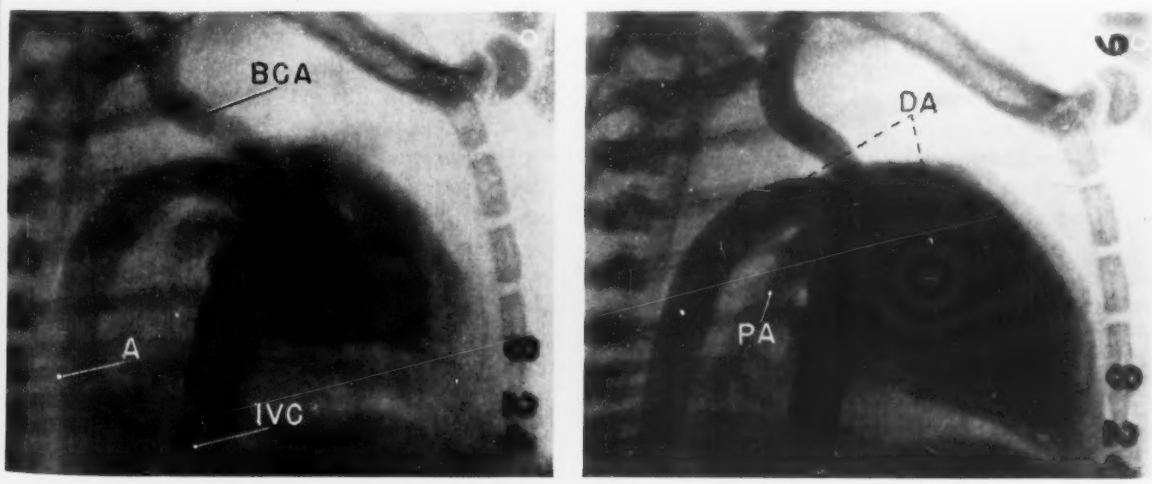

FIG. 7. Pictures showing a contrast medium passing in the blood from the umbilical vein to the heart by way of the large inferior caval vein (IVC). *A*: the prompt appearance of a good shadow in the aorta (A) and in the main branch going to the head (BCA) indicates a considerable flow of blood from the right side of the heart to the left through the foramen ovale, which lies in the septum between the two sides of the heart. *B*: 1 second later, there is a shadow in the pulmonary arteries (PA) and ductus arteriosus (DA). Hence blood flows from the right side of the heart into the pulmonary arterial trunk. Therefore, the stream must have divided in the fetal heart, part going to the right side and part to the left side of the heart.

per minute is less than double the top value, above. Consideration of the facts of the fetal circulation show why such high values are observed. In the fetus, most of the output of both ventricles of the heart goes down the descending aorta. Little blood flows through the lungs of a fetus, and the flow through the head is very slow and rather small in amount. In determinations of cardiac output in human subjects, only that blood which comes from one side of the heart, the right, is measured. Such data are not comparable, therefore, to those obtained in the fetus mentioned above.

How much of the blood flowing down the aorta ends up going to the placenta, instead of to the abdominal organs and other parts of the fetus? Calculations of flows in the umbilical arteries show that the volume of blood in the two arteries varied between 700 to 2000 cubic centimeters per minute. This, expressed as a proportion of the aortic blood flow, is about 63 per cent. The fact that nearly three-fourths of the blood put out by the heart goes down the aorta and approximately two-thirds of this blood goes to the placenta, testifies anew to the tremendous importance of the placenta for the welfare of the fetus.

What determines how much blood will go to the placenta? Is it the length of the umbilical cord, or the sizes of its vessels? Or is it governed by some other conditions? Earlier studies of umbilical cord blood flow[2] have shown that, as long as the diameter of the umbilical blood vessels remains above a critical point, very little energy is lost in the flow of blood from one end of the cord to the other. In fact, the blood literally pours from one end to the other under the impetus of a head of pressure fluctuating with the output of the heart. This suggests that the amount of blood passing to the placenta is primarily related to the volume put out by the heart. Such, in fact, is the case, as the following considerations show. When the volume of blood flowing to the placenta per minute is divided by the weight of the fetus, a fairly constant unit of flow is found. It is between 300 and 400 cubic centimeters of blood per minute per kilogram of body weight. Since the volume output of blood by the heart increases with the size of the organism, it is clear that the placental flow receives a fractional proportion of that output, the amount increasing as the fetus nears term.

What practical lessons, if any, may be learned from the fundamental facts of a physiological nature just described? It would be strange, indeed, if they were not reflected in more effective management of the baby at the time of childbirth. There is one major lesson that has been discovered and already applied. It relates to the inevitable redistribution of blood within the organism taking place when the lungs are first inflated.

At this time, the volume of blood necessary to fill the pulmonary blood vessels increases. This is at the expense of blood throughout the rest of the body, and it is associated with a transient but marked fall in blood pressure. Clearly, if more blood were available for the baby, both of these conditions would be minimized. There is a way to help this situation. This is to obtain blood for the baby from the placenta before the umbilical cord is cut. Such a practice is now a generally employed procedure among obstetricians, although the objective is different from that cited above. After the baby is born, it obtains no iron from its mother's milk, so it must depend upon its own stores in blood and muscle hemoglobin to satisfy its needs for growth until iron is available as a dietary supplement to milk.[5] The present practice of delayed clamping of the cord may add more than 60 cubic centimeters of blood from the placenta to the blood of the body. This is not an inconsiderable amount. In a baby weighing seven and one-half pounds, the quantity of blood in the body is about 300 cubic centimeters. Thus an increment of 60 cubic centimeters is an increase of twenty per cent. The immediate benefit of this volume of blood is to increase the volume of blood, and not the iron alone. This aids in restoring the blood pressure, and so helps to complete the circulatory adaptations to birth.

Among almost all animals, including certain primitive women, the transport of blood from the placenta to the baby prior to birth is aided by the relation of the position of the newborn relative to the placenta in the act of birth. It is below the latter, so that blood flows by gravity into the newly born organism. In many civilized cultures, it is clinical practice to nullify this by employing a birth position for the mother that is more convenient for the attendant. Then, upon birth, the baby is lifted into the air, and the umbilical cord clamped, sometimes after a few minutes delay.

The importance of the position of the baby in relation to the level of the placenta has been studied by Dr. Mary Gunther, of University College Hospital, London, and by Dr. Simon Duckman, of Brooklyn, New York. These obstetricians have observed that if a baby, still attached to the placenta before the latter is delivered, is placed upon a scale, the weight of the baby will vary according to the position of the baby relative to that of the placenta. If the baby is held below the placenta, the baby gains some 30 to 60 grams in weight in

less than a minute. This is enough blood to aid materially in the inevtiable and extensive hemodynamic alterations that take place at the time of birth.

Such conclusions as this concerning the basis of the adaptive mechanisms of the body to birth testify to the fitness of the organism which can be achieved through evolution. Taken in conjunction with those other circulatory mechanisms that cater to the needs of the organism as long as it is a fetus, but which disappear by a series of subtle adjustments when the newborn first inflates its lungs, they make the most complex inventions of the human mind seem small.

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August 21

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BOOK REVIEWS

AFRICA

Africa: A Study in Tropical Development. L. Dudley Stamp. vii + 568 pp. Illus. + maps. $8.50. Wiley, New York; Chapman & Hall, Ltd., London. 1953.

NO living geographer has seen more of the world than L. H. Dudley Stamp. To his masterful studies on Asia, *Land Use in Britain*, and his many other volumes on different parts of the world, he now adds an analysis of Africa. Since he has traveled widely in that continent, his book has the sure touch of one who has seen and understood. This volume at once takes its place as the definitive study of the continent. The author is interested in man's use of the land, so it is but natural that he stresses agriculture rather than minerals or political geography. At the same time, his geological background gives him a solid physical base. The emphasis is on tropical Africa.

Professor Stamp is uniquely equipped to compare Africa with the other continents. He finds it distinctive in its geography as it lies "athwart the equator," and "projects almost equally into both the northern and southern hemisphere. . . . The bulk of its 11,700,000 square miles lies within the tropics, so that Africa is essentially the world's problem continent where development under tropical conditions is concerned. Africa has other claims to urgent world attention. By Western standards much of the continent is underdeveloped, with resulting poverty and misery to its inhabitants, and with a further consequence that resources of interest to the outside world in minerals, agriculture, and forest products remain unused."

Stamp recognizes four great realms: the Mediterranean, which is part of the Moslem world; western Atlantic Africa, which is tropical Africa par excellence; eastern Africa, and southern or white man's Africa. The first nine chapters unroll the map and sketch the story of climate, soil, people, and transport. Eleven regional chapters follow, with a final survey of African problems and a statistical summary.

Most of the volume is properly filled with detail, but throughout the book the reader will find significant generalizations. Thus, "Morocco, Algeria, and Tunisia, though situated in Africa, form a region so apart from the remainder of the continent that they might almost have been excluded from a book dealing with Africa, the tropical continent." Or, "The development of the Gezira irrigation area is a fascinating story. It is the supreme example in Africa of a successful co-operative scheme between European management and African cultivators settled in an orderly way on the reclaimed land . . . It was in fact the largest peasant agricultural co-operative in the British Commonwealth."

The last chapter deals with the past, present, and future; and there both the general reader and the scholar will find much of interest. Several things have helped to transform Africa so rapidly. The first is the development of transport, a mobility that has disrupted the old tribal positions, made possible rapid economic development, and changed political administration. All this has brought a rise in the standard of living, with changes in food, clothing, and occupations. The export trade has greatly increased, with new products such as iron ore, bauxite, tin, chromium, manganese, and cobalt, in addition to the traditional diamonds, gold, and copper.

Out of a population of 198 million, those of European origin number 5 million. Fifty million live in the four independent countries, those under control of the United Kingdom number 57 million, 42 million are in the French Union, 15 million live under Belgian direction, while 11.5 million are under Portugese rule, and 1.6 million live in Spanish areas. United Nations Trust Territories account for 17.6 million.

This story of Africa is both professional and meaningful. It is the most interestingly written of the author's many books, and will be acclaimed by all who have any concern with the social, economic, and political development of this coming continent. The volume is handsomely illustrated by more than 200 photographs and maps, reproduced in excellent style.

GEORGE B. CRESSEY
Maxwell Professor of Geography
Syracuse University

THE POPULAR QUEST FOR SCIENCE

Explorations in Science. Waldemar Kaempffert. vii + 296 pp. $3.50. Viking Press, New York. 1953.

A healthy future for science depends on the dissemination of the results of research to a wide reading audience. Some scientists are willing and able to write for the layman, but many lack inclination or talent for communication beyond their esoteric circle. That function is now largely served by the science reporters, whose craft is increasingly important for scientist and layman alike. The reporting of science as spot news has problems that are absent in other fields of news gathering and that have not (from the point of view of the scientist, at least) been completely solved. It is in the longer review article that the best of the science reporters have achieved greatest success, and among the best is surely Waldemar Kaempffert of the *New York Times.*

In his most recent book the author has gathered and revised twenty of his periodical articles. They are not (as the blurb would have us believe) "a complete guided tour . . . of today's increasingly important scientific advances." They are a fascinating personal selection of some topics along the highways and some along the byways of science and technology. They range

A-bombs to Zworykin (on weather prediction and ol). Between A and Z the diet, if not balanced, is nly varied: atomic power plants, solar engines, atmospheric stratification, supersonic planes, flight, astronomy (from Palomar), mechanical tutes for human organs, the nature of the human cancer, psychodrama, science and social change, Wells as social reformer, and others. The inter- the reader of SCIENTIFIC MONTHLY is less in the nts of the articles (although he, too, will surely something) than in the selection and presentation. appeal of the chosen topics is evident. Standards of age and accuracy range from high to, at worst, uate. The style is readable and attractive, journal- in the best sense, and only occasionally so staccato obscure some of the links in thought.

he author has predilections and limitations con- nt with his own aims and therefore meriting notice not criticism. In the tradition of good science re- ing, he does not ignore past failures and present rtainties but he does stress future supposed bene- He is more at home with engineering and invention with science, strictly speaking. As a rule (and this so evident in the choice of subjects) he has more sp and insight for the physical sciences and their ap- ations than for most other subjects. Examples, ong many, of these (perfectly legitimate) tendencies his stressing the putative use of synthetic proteins make fur coats or his inadequate and sometimes er- eous understanding of the history and present status evolutionary theory. Many professional scientists will estion some of his ideas on the scientific mind and the processes and philosophy of research.

The chapter on "luck" is hardly up to the author's al standard, and that on ciphers and codes can only called mediocre, in addition to the fact that it cer- nly is not an "exploration in science." It is unfortu- e, too, that the book should close with a chapter on ken treasure which is excellent in its field but is de- edly outside the field of the book as a whole.

By the most stringent standards Mr. Kaempffert has batting average of at least .750, which is good in league. This book includes fine examples of science orting, and scientists are fortunate to have such an erpreter.

G. G. SIMPSON
merican Museum of Natural History
w York City

THE PURSUIT OF THE STARS

he History of Astronomy. Giorgio Abetti, translated from the Italian by Betty Burr Abetti. 338 pp. Illus. $6.00. Schuman, New York. 1952.

stronomy for Everyman. Martin Davidson, Ed. 494 pp. Illus. $5.00. Dutton, New York. 1953.

ALTHOUGH astronomy is the oldest of the sciences, it is also one of the most active. This shown by such recent advances as the development f radio techniques for studying the heavens and the revision of the astronomical measuring scale which gives a new set of values for the distances of the outer galaxies, double those previously accepted.

Doubtless an astronomer can get along without knowing much about the history of his science, but he can view these new developments in better perspective if he has some knowledge of the steps that led to them. This excellent book, *The History of Astronomy,* will give him that background, starting as it does with the ideas of primitive man and ending with the 200-inch Hale telescope at Mt. Palomar.

Dr. Abetti, director of the Astrophysical Observatory of Arcetri, near Florence, Italy, is a leading authority on the Sun and also on the history of astronomy, particularly Galileo, whose collected works and letters he has edited. This is peculiarly appropriate, since Galileo spent the last years of his life at Arcetri, and did his early work at Padua, where Abetti was born.

Fortunately the author's career has not been confined to his native Italy, but has been international. He has worked at Berlin and Heidelberg, as well as at the Yerkes and Mt. Wilson Observatories in the United States. This has helped him to write a book that is remarkably free from nationalistic bias, in which ample credit is given to the work of Americans, Englishmen, Germans, Frenchmen, and others, as well as Italians.

The first part of the book, 63 pages, takes us from the Chaldeans, Greeks, Romans, Hindus, Chinese, and others of ancient times, through the Middle Ages, when the Arabs made the principal contributions. The next 86 pages deal with the reformation of astronomy in the 16th and 17th centuries by Copernicus, Tycho Brahe, Galileo, Kepler, Huygens, Cassini, Newton, and their contemporaries. The remainder of the book, more than half, is devoted to the modern era, coming up to the 20th century concepts for which men such as George Ellery Hale, Sir Arthur Eddington, and others were responsible.

The final chapter is an account of the International Astronomical Union and its important activities, as well as the author's views of the future of astronomy. He foresees continued new discoveries and results, made possible by increased numbers of astronomers with ever more powerful means of investigating the sky, and by ". . . the assistance which the related sciences in the theoretical and experimental fields lend to astronomy in increasing measure."

The illustrations, for which the author is probably not responsible, are grouped together in one 32-page section. While they are well reproduced, they seem to have been chosen with little thought, since many relate to matters not discussed in the text. It seems strange, for example, to see among all the serious subjects a reproduction of an old print of "the inhabitants of the Moon, as seen through the telescope of Sir John Herschel," without any indication that this was a famous hoax, perpetrated by an American journalist in 1835. Certainly there should be a picture of the 200-inch telescope; actually there are three, two of the instrument itself and one of a model. This seems too much of

a good thing. Some pictures taken with it, of which there are none, might well have been substituted for two of these.

Astronomy for Everyman, of British origin, is of quite different character, although one chapter does give a concise history of the subject. In fact the various chapters cover almost every phase of astronomy, including the aurora and zodiacal light, and navigation. There is a short chapter on the possibilities of rocket flight to other planets by that prolific writer on such subjects, Arthur C. Clarke, chairman of the British Interplanetary Society.

Special emphasis is given the nearer objects, perhaps with good reason, since these are most familiar to the lay reader to whom the book is addressed. Certainly the Sun and Moon deserve the chapters they have been given, but it seems somewhat provincial to limit the account of the external galaxies, the largest and most distant objects studied by astronomers, to less than seven pages at the end of the chapter on the stars.

However, the book does give a good summary of many of the most interesting and significant aspects of modern astronomy. The authors, most of whom are officers, or former officers, of the British Astronomical Association, which is mainly an amateur group, know their subjects well and write about them in a manner that is both interesting and authoritative.

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CULTURAL CHEMISTRY

Man and the Chemical Elements J. Newton Friend. ix + 354 pp. Illus. + plates. $6.00. Scribner, New York. (Printed in England.) 1953.

"A truly human document." These are the author's own words (p. 261), used in commenting on the Egyptian Papyrus, Anastasia I, but no phrase of mine could more aptly characterize *Man and the Chemical Elements*. It is thoroughly delightful throughout. There are twenty-three chapters, each devoted to a group of chemical elements arranged according to Mendelejeff (or perhaps we should say Newlands out of deference to the pro-British enthusiasm of the author), historical anecdotes collected by a genuine scholar who is careful to distinguish fact from fiction, for instance (p. 21): "The Priestley statue in Birmingham represents Priestley heating the oxide in a tube with the sun's heat concentrated by a lens held between his thumb and second finger. Poetic licence! The actual lens was twelve inches across! Legend hath it that Priestley discovered the gas on 1st August 1774. . . . His first public announcement was at the Royal Society on 23rd March 1775, and in most cases that would now be taken as the date of the discovery." Or (pp. 102 and 144): "Before long a large battery was installed for research purposes in the Royal Institution under the direction of Humphry Davy. It had 2000 pairs of plates—copper and zinc—with a total surface of 890 square feet. With its aid in 1807 Davy was able to isolate for the first time the alkali metals sodium and potassium. . . . Napoleon was extremely angry that the honour of discovering the alkali metals should have fallen to the English . . . (He commanded an electric battery) . . . made at once and when it arrived he called at the Academy to see it. Before any one could stop him he placed the terminals in his mouth: to try the strength of the current. The shock on his tongue must have been terrific; he left the Academy without a word!"

Thorough treatment is given diamonds (pp. 55–67), thermometers (pp. 221–227), nails, from the ancient to the modern threaded nail (pp. 285–289), and standards of length and mass, including monochromatic light from Hg-198 (pp. 306–310). One wishes that the account of the H-bomb were up-to-date: tritium is not mentioned, and the reaction $4H \rightarrow He$ which is fully treated is unsuited to terrestrial use.

Thousands of interesting facts catch our attention, for instance: the Monarch of Moscow bell cast in 1733 and weighing 200 tons, but cracked in casting and therefore inarticulate (just as the Russian vacuum cleaners made two centuries later wouldn't vac) . . . the famous Delhi pillar of wrought iron, perhaps unconsciously kept from corroding these 1700 years by the ceremonial butter with which it is annointed at religious festivals . . . the name plutonium, suggested over 100 years ago by Clarke of Cambridge for an element that was later called barium . . . and the meteor that fell in Eastern Siberia in 1947, largest in the memory of man—1000 tons, compared with the famous Rowton meteorite of 1876 that weighed a mere pounds.

Any teacher of general chemistry should forever have a copy of this book within his grasp as an unending source of human-interest stories about the chemical elements—enticing scientific bait for the beginning student who is still alien to science but native to history. Other scientists who read this in their lighter hours will derive continuing pleasure from it.

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POPULATION PRESSURE

Hungry People and Empty Lands. S. Chandrasekhar. 306 pp. Illus. $3.50. Indian Institute for Population Studies, Baroda, India. 1952.

THIS is a book dealing with the relation of international tensions to the growth of population and to the economic development of the "underdeveloped" areas of the world by an Indian student. His thesis is that international tensions are at least aggravated, if not caused, by differentials in level of living due in large measure to the unequal pressure of numbers of people on the resources available for their maintenance in different political areas. He cites the now well-known facts regarding differentials in population growth and resources in different countries, but he quite naturally

draws heavily on the data relating to Asiatic countries having small resources in comparison with their large and growing populations.

Dr. Chandrasekhar, while believing that there are still considerable unused resources in the world that could be made available to the needy peoples through emigration, argues that the universal control of population growth must be one of the essential elements of any world policy calculated to improve living conditions in the underdeveloped areas and thus to ease the tensions between such nations and the more favored areas of the West. He also urges the need for the complete liquidation of the colonial system, for large scale industrialization, and for the improvement of agriculture as bases for a better level of living, but repeatedly he comes back to the point that without the control of population growth these other parts of a broad program of economic improvement will be of small avail.

The book is written with conviction and vigor and the reviewer finds himself in basic agreement with Dr. Chandrasekhar on all important points, although he has, perhaps, less faith in the substantial alleviation of the hard lot of the Indians, Chinese, Japanese, and other hard pressed people through migration to the less densely settled areas of the earth. He would also be inclined to emphasize somewhat more than the author the need to show these underdeveloped peoples how their poverty has arisen in the past and will continue to harass them, in large part, because of their too great numbers. However, the author has done a good job in surveying the world population situation and in presenting it as it appears to a man in, perhaps, the most important of the underdeveloped areas.

The reviewer regrets that an otherwise excellent book is occasionally marred by a lack of precision in presenting small details of fact that, while not resulting in actual distortion, may give some readers an impression of careless treatment and thus prejudice them unduly against the conclusions of the author. The reviewer greatly hopes that this book will secure wide circulation among thoughtful people not only in the underdeveloped areas of the world but in the West that, willy-nilly, must accept much of the responsibility for the population and economic changes and the tensions resulting therefrom in these less favored areas.

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FOOD LORE

Man's Foods. J. B. Jensen. x + 278 pp. $4.50. Garrard Press, Champaign, Ill. 1953.

AS stated in the subtitle of this book, it is concerned with nutrition and environments in food gathering times and food producing items. Dr. Jensen has developed a fascinating subject, tracing some of the nutritional influences on man's development. The book has been divided into two sections: the food gathering times which begin with the foods of the pre-Chellean-Chellean to the Mesolithic periods of Europe, and the food producing times. This second part includes chapters on cereals, foods of orchards and gardens, animal foods, climatic stress and nutrition, and social aspects of nutrition. This illustrates the broad fields that the author has covered. In fact, what may be one of the chief criticisms of the book is that the author has so much information that the book seems poorly organized. Because of the tendency to skip from subject to subject somewhat rapidly, the book is not easily read. The book is devoid of illustrations which could have brightened it considerably. The author has gathered his information from the anthropologist, the explorer, the chemist, the physiologist, and the nutritionist and, as with any book dealing with so many aspects of food and its contribution to progress, there will be parts with which some may not agree. For example, the nutritionist surely will take exception to the table of nutrient content of wheat in the chapter entitled cereals. The table is not in agreement with the U. S. Department of Agriculture Handbook No. 8. The table is not documented and it is poorly arranged.

Nevertheless, the reader will find the book interesting. The author has a way of inserting interesting quotes in the right places. For example his little quote from a Sumerian milker (5000 years ago) which he says cannot be vouched for, "that if the gods wanted man to have clean milk they would have placed the udders on the forepart of the animal," makes the reader want to read on to find out what more modern people think of the practicality of milk and milk sanitation.

There are about 600 references listed. These include the works of explorers, anthropologists, and historians, as well as chemists and nutritionists. The author has made wide use of data from the many fields that contribute to the very interesting subject of food and man's physical and social growth.

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MAPS

Elements of Cartography. A. H. Robinson. vii + 254 pp. Illus. $7.00. Wiley, New York. 1953.

THE past decade may well mark a renaissance in the ancient science of cartography. For centuries cartography has been considered a manipulative subject consisting mainly of map drafting. Dr. Robinson brings us a fresh approach with his stimulating theme that cartography is an "intellectual art and science."

The author, a professionally trained geographer and cartographer with several years wartime experience in governmental mapping activities, is eminently qualified to present this new approach. In addition, he has had experience in teaching cartography and has done out-

standing research in methods of cartographic presentation and the analysis of cartographic technique.

Robinson has competently selected the subject matter of this book in accordance with accepted philosophy of geo-cartographic training. All of the conventional aspects of modern cartography are presented in a balanced and well organized manner. Two chapters (The Employment of Projections, and Map Design) stand out as highlights, not because they are superior in presentation, but because much of the material covered in them is usually lacking in cartography texts.

The chapter on The Employment of Projections, focuses attention on the qualities of projected earth grids, the characteristics of a variety of map projections, and the criterion for selecting the proper projection to suit the map purpose. The excellent illustrations together with well organized textual matter bring the reader a visual as well as a written understanding of map deformation. This presentation of an oft considered cartographic bugaboo should dispel apprehension of the uninitiated.

It is in the chapter on Map Design (VII) that Robinson's theme of cartography as an "intellectual art and science" is most fully developed. Particularly noteworthy are the new concepts in sections on visual outline, visual significance, clarity and legibility, color in cartography, contrast of value, contrast of pattern, choice of colors, balance and layout, titles and legends, and effects of reduction. Again, excellent illustrations lend significance to these new departures. Here as elsewhere throughout the book Robinson has applied the findings of research done in allied fields of design, typography, and visual psychology. If it were necessary to single out the most important contribution of the book it would have to be Chapter VII. Nowhere else is as complete and competent a discussion of map design available in the English language.

Elements of Cartography will be a welcome addition to the libraries of traditional makers of maps, such as geographers, geologists, engineers, and military men. It should also prove to be very useful to authors in other fields who find it necessary to compile and draft maps to accompany their own publications.

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THE AMATEUR WEATHER PROPHET

Weather Inference for Beginners. D. J. Holland. xiii + 196 pp. Illus. $6.00. Cambridge University Press, New York. (Printed in England.) 1953.

PUBLICATION of books like *Weather Inference for Beginners* (made clear in a series of actual examples), indicates the presence of a sizable market in Great Britain for nonfiction bordering on the professional level. Although the author points out in his preface that "this book is for all who are interested in their own daily weather," by page 2 he is discussing *total* versus *local* changes in a fluid's properties. Similarly, various standard meteorological symbols are introduced and used briefly, such as φ, ρ, λ, ∇p, θ, α and Φ, as well as ψ, the stream function. Even a vector cross product appears on page 85. Thus, this book actually provides the novice with a brief but comparatively high-level introduction to practically all the major concepts of modern meteorology, including blocking action, jet streams, thermal winds, potential temperature, extinction coefficient, solenoids, ridge and trough theory, convergence and divergence, Richardson number, virtual temperature, entropy, geopotential, isentropic surfaces, thickness lines, isallobaric winds, and thermodynamic charts, particularly the tephigram.

Contrasting sharply with this quasi-professional approach are long lists of consecutive weather observations throughout the book illustrating weather changes on which the technical explanation is based. Although these observations were made near London, England between September and December 1936 in a mixture of official and nonofficial codes, the observations do not achieve their purpose in providing a framework for the technical discussion, in the reviewer's opinion. Instead the listings require the perusal of tedious weather notations long before the reader thoroughly understands the meteorological mechanisms involved. Moreover the weather inferences based on single and multiple station observations, though intersecting and well described, probably are applicable in North America only in the Pacific Coast region between Oregon and Alaska where the air-mass sources and storm tracks are somewhat comparable to those affecting London, England.

The professional meteorologist is likely to find the section on the balance of atmospheric radiation helpful in preparing classroom lectures. The section on wind scales contains a new universal scale which the author considers one of the easiest to use when deducing gradient wind from a single diagram. In conclusion, it is noted that in contrast to many of the postwar books printed in Great Britain, this one is printed on semi-gloss paper, in large type, and with wide margins that combine to provide a pleasing typographic product.

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ARTIFICIAL RESPIRATION

Adventures in Artificial Respiration. Peter V. Karpovich. xvi + 303 pp. Illus. $7.50. Association Press, New York. 1953.

THIS book presents an extensive historical account of the development of methods for artificial respiration, well and fully illustrated with photographs of many of the leaders in the field. The reader is surprised to learn of the large number of techniques introduced over the last century. The changes in practice over the years (from Silvester to Schafer, and from Schafer to Nielsen, as the most widely accepted authorities) are described in great detail, with some account of many other methods. A table is included, 18 pages long,

ach 105 different procedures are briefly described, cluding both single and double phase methods. The xt is written in rather colloquial style, with many iticisms, some rather forced, but the total impres- n is stimulating and informative.

There is a good account of recent studies of artificial spiration in normal people, ending with Gordon's ob- rvations on 26 heroic anesthetized and curarized sub- cts, totally unable to breathe on their own, in which e superiority of the Nielsen arm-lift back-pressure ethod over the older Schafer prone-pressure technique s conclusively demonstrated. The evidence suggests at the Schafer method is inadequate, not only because moves too small a volume of air, but because this lume is not properly distributed in the lungs.

The normal physiology of respiration is discussed in veral chapters, at a rather elementary level. The eatment of the Hering-Breuer reflexes leaves much be desired. It omits recent work that shows that nsory nerve impulses from lung receptors are almost rtainly not responsible for the onset of a new inspira- n, however important they may be in bringing it to end. Sufficient attention is not given to the recent vival of the concept of intrinsic rhythmicity of the spiratory centers.

The author has made many contributions to the sub- ct, and has been closely associated with the research nsored by the Armed Forces, under the direction Dr. D. B. Dill. In this program he has carried rough metabolic studies that have shown that, in ob- ining the more favorable results of two-phase meth- s, the operators exercise much more vigorously than the older techniques, thus greatly increasing their ygen consumption. At the same time their subjects ow no change in metabolic rate, if the methods be perly used. Injuries and distress, in both operators d subjects, are discussed, and suggestions are made r minimizing such incidents. The book closes with a mmary of the most important material, intended as guide for instructors in life-saving.

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THE WORLD AROUND US

ur Physical Environment: A Problem Approach. Leonard W. Gaddum and Harold L. Knowles. ix + 625 pp. Illus. $5.50. Houghton Mifflin, Boston. 1953.

THE authors of this textbook for an integrated course in the physical sciences voice two principal bjectives: a comprehensive picture of man's physical nvironment, and the encouragement of reasoning abil- . In choosing material, those factors that have been ost important in influencing civilization are given first nsideration. An excellent introduction on environmen- l factors and the nature and applicability of scientific ethod is followed by sections on space and time, eather and climate, native vegetation, topography, and material resources and energy resources. The fundamentals of physics and chemistry appear in the last two sections of the book—an inversion of the customary approach. Each of the sections is prefaced by a discussion of the relative significance of the environmental factor that is to be developed. Included at the end of the book is a bibliography of seventy-three suggested readings on basic knowledge, scientific method, and social and environmental problems.

A distinctive feature of the book is the extensive problem lists at the end of the chapters. These provide great variety, and include drill exercises, problem situations requiring application of principles and methods discussed in the text, and others based upon excerpts from literature and the diaries of travelers and explorers. As the book progresses, review questions are prominently featured in the lists. It is clear that the authors have given much time and effort to these lists, and if as much time is devoted to them in the classroom and study as they deserve, the authors are well justified in calling the work a "problem approach."

The book is attractively printed and illustrated. Important ideas and principles are set off in black-face type. The style is conventional. Difficulties are not sidestepped and important concepts (such as pressure and humidity in the section on weather and climate) are adequately developed as they are needed, a feature that contributes to the integration. This book should be a valuable aid in reaching the objectives set by the authors. It is an excellent addition to the list of textbooks on the physical sciences.

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Man and His Physical Universe. Richard Wistar. xv + 488 pp. Illus. $4.75. Wiley, New York. 1953.

THIS is a provocative book that might be misjudged if cursorily examined. Written as an integrated approach to the study of physical science, materials are drawn from the fields of physics, astronomy, meteorology, geology, and chemistry. In the choice of material, the assumption is made that student interest and retention is greater when attention is focussed on phenomena that are an intimate part of the student's experience. For example, photography serves to introduce the principles of optics and wave motion, and this leads naturally into sound and the physical basis of music. Weather lore points up the need for a scientific basis of forecasting. Pressure and its measurement, gas laws and kinetic theory, work and heat, are then studied as a rational basis for the analysis of weather and climate. Communication by telegraph, telephone, and radio, and the electrical system of the motor car, lead to the exposition of the major principles of electricity. An account, in historical sequence, of the major developments in atomic structure and energy ends the book. Succinct chapter summaries are provided. The study questions

are thought provoking and many of them require numerical computation. Scientific method is stressed and is correlated with the text; the limitations of the method are not considered.

The style is simple and direct and might be observed with profit by other writers of physical science textbooks. The terse, crisp sentences make easy reading. To one familiar with the subject matter, the author's sentences are often striking because of the range of implication. To the unitiated, the simple direct statements may lead to inaccurate impressions and a false simplicity if they are not accompanied by qualifying comment. It is a little surprising, for example, to learn that Bach "suggested" the fundamental basis for equal temperament, or to find that "the period between 1700 B.C. and A.D. 1700 was nearly barren of significant industrial and scientific achievements." Topics are frequently introduced by a barrage of suggestive questions. Mathematical formulae seldom appear and in those instances where they are needed, the relations are written out in words rather than in symbols. The author has done much toward making physical science interesting and exciting, and the book should appeal to the layman as well as to the student of physical science.

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DRUG ADDICTION

Conferences on Drug Addiction Among Adolescents. xvi + 320 pp. $4.00. Blakiston, New York. 1953.

THIS is the verbatim report of two conferences on drug addiction among adolescents held at the New York Academy of Medicine in November, 1951 and in March, 1952. The meetings were sponsored by the Committee on Public Health Relations of the Academy and subsidized by the Josiah Macy, Jr. Foundation. Fifty professional workers interested primarily in either the social problems of adolescence or in drug addiction participated—most of them from New York. There are a few short reports, or perhaps one might better term them memoranda, to focus the discussions. The bulk of the book consists of spontaneous verbal interchanges between participants. There is in consequence a good deal of repetition. The volume has a three page glossary of terms from drug-addiction argot, and a very extensive index.

Dr. Frank Fremont Smith, the Medical Director of the Macy Foundation, keynoted the proceedings when he said, "The most important thing that this preliminary conference can possibly do is to light up the areas of our ignorance." In justifying such meetings he makes use of Professor Cannon's very apt phrase, "the fertility of aggregation." Confessions from many of the participants of our great areas of ignorance of the myriad of problems connected with drug addiction punctuate the report.

There seemed to be general agreement that there existed in 1951 in New York City, and elsewhere in this country, a marked increase in the use of narcotics. In 1951, six hundred and sixty-two drug users between sixteen and twenty years of age were arrested in New York City—a great increase over the usual number. According to Dr. Haven Emerson, New York had a similar epidemic of drug addiction in 1911 that was not brought under control for five years.

Dr. Harris Isbell, the Director of Research at the United States Public Health Service Hospital for drug addicts in Lexington, Kentucky, has a short but comprehensive outline of the many subjects for psychiatric research connected with addictions. Professor Stanley Bigman presents the sociologist's point of view, emphasizing the importance of group pressures. Professor Maurice Seevers briefly reviews the animal experimental work and mentions his own experiences with his sixty addicted monkeys.

Here and there one can find points of clinical interest, such as the rarity of withdrawal symptoms in juvenile addicts, the reduction of the intensity of withdrawal symptoms by hypnosis, and the fact that heroin capsules commonly peddled generally consist of ninety-eight per cent sugar.

But, for those seeking specific information the report will prove disappointing. For those who are interested in learning the direction that the thinking of a group of competent and dedicated professional workers is taking, in dealing with this important social problem it will prove rewarding.

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SPADE WORK

Spadework in Archaeology. Sir Leonard Woolley. 124 pp. Illus. + plates. $4.75. Philosophical Library, New York. (Printed in Great Britain.) 1953.

IN this brief and easily read book a man who can be called the greatest living archaeologist gives us the benefit of his wisdom, acquired in fifty years of digging. The book is dedicated to Mohammed ibn Sheikh Ibrahim, now a member of the Syrian Parliament and head of an Arabian tribe. Hamoudi, as the sheikh is less formally called, served as Sir Leonard's foreman until after World War II, when he was succeeded at the excavations by his son Yahya. The book contains a photograph of a bust of Hamoudi by Lady Woolley and several anecdotes about his skill at handling workmen, protecting finds, and directing the most delicate kinds of excavation.

Sir Leonard's appreciation of Hamoudi is the key to his success in the field. Honesty and sincerity combined with mental alertness and native ingenuity are qualities that anyone needs to succeed in any kind of enterprise in the Middle East. The Arabs are keen students of human nature, treating each man according to his merits, and Sir Leonard did well in the test. He and Hamoudi

if one may judge by the wealth of amusing anecdotes with which this book is studded, are two of a kind.

His first dig was at a Roman site in the north of England in 1907. He then went to Nubia for five years; during this time he unearthed a vast number of curious specimens of a mixed African culture which have lately been the downfall of our experts on the University Museum (Philadelphia) television program. In 1922 he dug at Akhenaten's capital, Tell el Amarna. Then came work in Italy, and in 1911 he opened a huge site, the Hittite city of Carchemish in Syria, with T. E. Lawrence as his assistant. After time out for World War I, he returned there in 1919. His greatest work was at Ur, where he spent twelve years in the desert, and unearthed the magnificent specimens now on exhibition in Philadelphia, London, and Baghdad. It is characteristic of him that he waited five years before opening the royal tombs, in order to train himself and his men for this delicate and intricate task. For seven years before and after World War II he dug at another city-site near Hatay, on the Turko-Syrian border. In all of these digs he and Lady Woolley lived in the close quarters of expedition houses, with expedition personnel. No mention is made of the strain on the human nervous system this manner of life imposes.

This is more than a manual of how to dig, to handle workmen, and to deal with government officials. It is more than a collection of amusing anecdotes. It is first hand history and not the usual product of compilers. Sir Leonard, for example, thinks less of the godly qualities of the Pharaoh Akhenaten than do the standard historians, for it was Sir Leonard and not they who excavated that monotheistic king's wine cellar and harem, even finding the body of one of the ladies amid the jars. The city itself, he remarks, was shoddy, made of bright paint over cheap stone. No other subject could be represented by the royal sculptors except the monarch and his family. "At his death," says Sir Leonard, "his gaudy capital was deserted like a theater stage after the last curtain falls."

Even in his most formal reports Sir Leonard's writing is never tedious. In *Spadework* it is delightful.

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SOCIAL INSECTS

The Social Insects. O. W. Richards. 219 pp. Illus. + plates. $4.75. Philosophical Library, New York; Macdonald, London. 1953.

THIS book provides an excellent, readable account of the behavior of the truly social insects: that is, the termites, the ants, some bees, and some wasps. It is illustrated with several diagrammatic drawings and and numerous photographs.

The emphasis is on British (or at least European) types of insects, so that, for example, the stingless bees which abound only in the tropics are treated in but six pages of text. On the other hand, in many of the discussions, information on non-European forms is included, especially if such material contributes to an understanding of other social insects.

If one were to select a particular section for special comment, it would be the section on the wasps. This is no surprise since Dr. Richards is a specialist on these insects. His treatment of wasp behavior is the best that has been assembled in the relatively brief, easily read style of a semipopular book. Here, fortunately, the author has not hesitated to draw on his personal knowledge of tropical as well as temperate wasp biology, and on the recent studies of wasps made by French and Italian authors.

The rather meager treatment of subsocial forms whose behavior may provide clues to the origin of social behavior may be a disappointment to some. However, the last chapter, entitled "Insect Societies," makes up for some of the lack in this connection by discussing the principles involved in social behavior, prerequisites for social life, the origin of societies, and the like. On reading this book one is impressed not so much by items which might have been included, but by the great amount of material that Dr. Richards has been able to include in a short and thoroughly interesting book. We can recommend it not only to entomologists, but to the general reader as well.

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LETTERS

MODERN CULT OF RACISM AND THE BLACK MADONNA

THERE is an ironic sidelight on The Black Madonna which is the subject of an article by Moss and Cappannari [THE SCIENTIFIC MONTHLY, **76,** 319 (1953)] (not "*so-called* Black Madonna," as she is so often described, but truly Negroid black and with all of the other accouterments to go with her blackness). We learn from the authors that she is the *miracle-working* madonna ("We wish to emphasize that all the black madonnas mentioned above are 'miracle-working madonnas' ").

According to the article by Moss and Cappannari, these madonnas were descendants of one of the Demeters; not "the sorrowful Eleusinian mother" but the more *powerful* Demeter Melaina, the *black* Demeter associated with the earth and fertility. The Greeks built temples to her and the direct line from Demeter (or the Egyptian black Isis or the Roman black Ceres) and the Jesus and Resurrection story has long been noted. These black and Negroid figures get not "*dulia* and *hyperdulia*" (veneration and adoration) but "*latria*" (worship). ". . . The Madonna is worshipped for its power," observe the authors. In fact, it is accorded the greatest and most basic power, that of life itself. Even though religious sources deny the relationship between the black madonnas and the pagan Roman Ceres, they have at least one thing in common. After centuries, eons, of the cult of white worship, after waves of conscious effort to deny, obliterate, deface, paint, and destroy, the black madonnas remain, still believed to be more powerful for the help of suppliants.

The authors conclude that the black madonnas (Christian borrowings from an earlier art form) are equated with power ("They are implored for intercession").

The relationship between power and fear is undeniable. A fear that antedates recorded history is still upon us. In its modern form, it is the cult of racism. For the basic component of prejudices against darker human beings is fear. While it is true that "changes in the culture of any society are always influenced by the pre-existing customs and institutions of that society," also true is the observation that, for the most part, mankind is certainly not easily detached from the patterned customs and beliefs, which, in this instance, appear to have attached themselves to humanity—or at least part of it—right down to the present day.

MARGUERITE CARTWRIGHT
Hunter College of the City of New York

WE find Miss Cartwright's observations interesting. However, we make specific mention in our article that the madonnas under examination are *not* Negroid. Rather, the Negroid madonnas can be explained by an alternative hypothesis, as an attempt to anthropomorphize the Virgin. The extension of our remarks in the statement by Miss Cartwright is unwarranted by the data presented in our article. A careful examination of the data reveals that the evidence does not lend itself to the conclusions made by Miss Cartwright.

LEONARD W. MOSS
STEPHEN C. CAPPANNARI
Department of Sociology and Anthropology
Wayne University

THEOLOGICAL OR CULTURAL BLACKNESS

MAY I, after reading Moss and Cappannari's article, "The Black Madonna: An Example of Culture Borrowing" [THE SCIENTIFIC MONTHLY, **76,** 319 (1953)], express a perhaps critical opinion of it?

I found the article extremely suggestive, and I have no doubt that the authors have a workable thesis in their contention that some of the Black Virgins in Europe, more especially in the Mediterranean area, represent survivals of the cult of a black-faced goddess. However, after reading their discussion of said hypothesis, one is still left wishing that they had come closer to the point where a clean bill of proof could be granted them.

To come down to particulars, one cannot help wondering on what basic criteria their initial classification is made to rest. In tackling a problem of this kind, if I may suggest, it might have been advisable to proceed first to as complete a survey as possible of the cases of the Black Virgin in the area under study. This done, the material on hand could have been divided into those cases where blackness was clearly due to physical agencies, and the others where cultural or religious influences were to be suspected. Then, sharpening the focus, there might have been a discussion of blackness in earth-goddesses in the same area. After which—*hoc opus, hic labor est*—the crucial part of the problem could have been entered, that of confirming "adhesions" (E. B. Tylor's terminology) between representations of certain black pagan goddesses and those of the Black Madonnas today. For the Madonna della Spiga mentioned in the article, this seems to obtain most convincingly; not so, I am afraid, in several of the other cases.

Another insufficiently analyzed criterion is the power of working miracles as an attribute of the Black Madonna. Theologically, of course, the Madonna is everywhere, black or otherwise, capable of working miracles. Historically, however, certain of her representations have acquired a reputation for "working miracles," becoming the *raison d'être* of various popular shrines. This distinction is not to be dismissed as purely verbal since the authors' thesis rests on the possible identifica-

tion of some extant Black Virgins with shrines of the Earth-Goddess where the image itself was supposedly endowed with miracle-working powers.

The article, I am constrained to observe, labors almost throughout under an abundance of extremely luxuriant, but apparently not always relevant, information. The authors' thesis would certainly have come off to greater advantage if it had been disencumbered of such an overgrowth of sometimes rather elementary material. Too, it seems to me that evidence derived from literary sources such as St. Augustine or Guillaume de Digulleville could have formed the object of a separate section.

From the point of view of material presentation, the article is somewhat defaced, so to speak, by a number of "unidiomacies," but in most cases the meaning can be made out. One may query, however, the use of the term "cultural borrowing" which, I take it, is given here its common ethnological sense, where perhaps "survival" might have done better.

Coming down to typography, it may not unkindly be pointed out that "Nuestra Senora di Guadaloupe" (page 319) is distressing to the reader on three counts: first, the *n* of Senora should have a tilde; second, *di* is Italian; the preposition here should be *de*; and third, *Guadaloupe* is French, not Spanish.

I rather blush at the pedantry with which these remarks may appear to be redolent, but first and last, my complaint is that, possessed of a rather interesting hypothesis, Moss and Cappannari should seem satisfied, even at the end of their article, still to call it an hypothesis. One might be disappointed at less.

PAUL-LOUIS FAYE
Department of Modern Languages and Literatures
University of Colorado

WE should like to thank Dr. Faye for his helpful comment on our paper and his suggestions for the improvement in our style. There are, however, several thoughtful points in Dr. Faye's letter that demand answers.

The intent of the article was that of suggesting an hypothesis and, as such, our exposition, it goes without saying, would rest on partial, fragmentary, and incomplete evidence. Anything beyond this we feel with Hamlet would be "a consummation devoutly to be wished."

The writers are well aware of the theological view that God granted the Virgin special powers to perform miracles. However, our interpretation is not an orthodox theological one, but rather an anthropological or functional conception. We have simply suggested that the black madonnas are a special type of phenomena in that they have been regarded *as if* this supernatural power were intrinsic to the images. We are not here at all concerned with the grave theological question of the miraculous powers of the Virgin per se. Instead, we have simply suggested an *hypothesis* that might illuminate one *class* of black madonnas.

Dr. Faye's concern over our use of the term "cultural borrowing" seems unwarranted. We employed it as synonymous with "diffusion." Current anthropological usage calls for the employment of the term "retention," rather than "survival," which smacks too denotatively of Tylor's construct.

Since the writers had not expected to advance their thesis beyond the stage of developing a verifiable hypothesis, we warmly appreciate the constructive criticism advanced by Dr. Faye.

LEONARD W. MOSS
STEPHEN C. CAPPANNARI

SONG OF SONGS

IN a footnote, page 324, to their article "The Black Madonna: An Example of Culture Borrowing" [THE SCIENTIFIC MONTHLY, **76,** 319 (1953)], Moss and Cappannari failed to identify correctly the passage from the *Song of Songs* which they quote as an introduction to the subject matter. They hold it to be a "conversation between King Solomon and his Black Queen." They add ambiguously: "The intent of the original Hebrew version clearly sets forth the relationship between the two lovers." However, for every serious student of the *Song of Songs,* these two lovers are not the royal couple but a shepherdess, tanned by the sun of her native Palestine, and her bridegroom, also of lowly origin. By rabbis as well as by Church Fathers, the *Song of Songs* has been allegorically reinterpreted in order to justify its inclusion in the Holy Scriptures; but never has it been misunderstood as a dialogue between Solomon and a black spouse of his.

Is it really necessary to tell scientists that there is no other "version" of the *Song of Songs* but the "original Hebrew" one? A translation, whether the King James Bible or any other, never becomes another "version."

May I close with the appeal to treat references to the Bible in the future with the same seriousness and thoroughness as any other source material.

L. SELIGSBERGER
1603 Harrison Avenue
Wlimington 3, Delaware

SINCE Mr. Seligsberger has leveled the charges of ambiguity and misinterpretation at the footnote passage in our paper, we feel it necessary to elaborate on an area which is merely tangential to our thesis.

An examination of the literature will reveal a plethora of interpretations regarding the *Song of Songs.* There have been many theological controversies waged on the passages of this Book. Both Jewish rabbinical synods and Roman Catholic scholars have attached a mystical interpretation, treating the Song as an allegory of God and His people (or Church). It is on the basis of this mystical view that the Song has been included in the Jewish Passover liturgy and in the various versions of the Holy Scriptures. However, this is but one approach to the interpretation of the Song.

In the third century A.D., one of the Church Fathers, Origen, described the Song as an epithalamium sung at the marriage of Solomon with the daughter of an Egyptian Pharaoh. Ample evidence has been amassed to

warrant the discard of this hypothesis. More recent interpretations hold that the story is a collection of rustic folksongs used in connection with wedding festivities in the North of Palestine and Lebanon.

The authorship of the Song is commonly credited to Solomon. However, serious objection to this claim has been raised by many students of the Bible. The style and language of the passages are those of an age much later than the time of Solomon. Evidence of Greek culture diffusion is present in the Hebrew text. It is entirely possible that the Song was written some four hundred years after the time of Solomon. Be that as it may, the name of Solomon was attached to the work.

Hebrew scholars describe the story as one concerning the trials of a Shulammite maiden who is in love with a shepherd. Her brothers, disapproving the union, put her to work tending the vineyards where she is blackened by the sun. Courtiers of Solomon chanced to pass the vineyards and were impressed by the rare beauty of the Shulammite. They attempted to persuade her to accompany them to Solomon's Court. After her refusal, they led her away as a captive. Solomon tried to win her love and sang of her beauty. But the maiden remained true to her shepherd lover.* This then is the explanation of our interpretation in the footnote.

Mr. Seligsberger is, no doubt, unaware of the specific use of the word "version." Webster's Dictionary indicates ". . . a translation or rendering of the Bible or a part of it; as, the Authorized and Douay *versions*."

LEONARD W. MOSS
STEPHEN C. CAPPANNARI

* An interesting commentary and translation of the Song by Rabbi Dr. S. M. Lehrman may be found in: *The Five Megilloth*. A. Cohen, Ed. x – xiii, 1–32. Hindhead, Surrey: Soncino Press. (1946). *Megilloth*: Hebrew, meaning *scrolls*.

CURRICULA AND EDUCABILITY

PROFESSOR CAIRNS portrays a problem of the utmost seriousness in his article entitled "Mathematics and the Educational Octopus" [THE SCIENTIFIC MONTHLY, **76**, 231 (1953)]. It is inevitable that, as the base of education is broadened to include a larger and larger proportion of a population, a corresponding dilution of content must occur. No one can deny that every citizen must have the right to be educated, but it is equally true that persons and segments of the population vary in their educability.

The objectives to be attained by the "life adjustment" movement are in themselves fine and worthy, but surely should not represent the whole of the goals of education. In themselves they form only the base of good citizenship common to all our people. However, if they are construed to be the end point as well as the common base, then serious damage results. This is extremely well pointed out in Cairns' article in the words—". . . the false argument that the studies in question are good only for the college-bound minority. Hence, by a gross misinterpretation of democracy, these subjects are crowded out, to the detriment of everyone. . . ." This is exactly the misinterpretation always associated with the Lincolnian "All men are created equal." This, of course, means equality in opportunity and not in size, strength, or mental ability. Must we proceed to use the same false arguments to govern the future pattern of our educational processes?

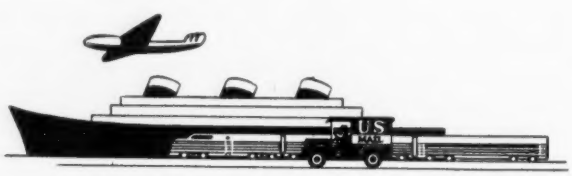
The "life adjusters" exhibit themselves as gallant champions in a great controversy between liberalism and traditionalism. The application of cold common sense shows the problem really to be one resulting from our increasing social and technological complexity. What is needed is to strip off certain deadwood details of accumulated results of man's inquiries of the past in order to prepare for a still more complex future. I would call this an endeavor to bring about modernization of traditional content while securing and maintaining rigorous standards. This is true within any given discipline and especially mathematics. This attitude is distinctly that of Professor Cairns.

Why has the Mathematical Association of America appointed a committee to appraise the present undergraduate mathematical curricula and to make recommendations concerning their betterment? Obviously, to meet this very need. This slackening of standards and this attrition of content, begun by persons trained in college themselves, must now be corrected by a movement beginning in the colleges.

In order to insure that our total educational system of the future is a healthy one, we must modernize content, develop and maintain high standards of performance on the part of the learner (and obviously the teacher), and offer to everyone, based upon his ability to learn and to profit, access to all areas of man's knowledge by appropriate curriculum offerings at the various levels of our educational segments.

PAUL H. KRATZ

Washington, D. C.



ASSOCIATION AFFAIRS

SANTA BARBARA MEETING OF THE PACIFIC DIVISION

THE thirty-fourth annual meeting of the Pacific Division, AAAS, was held in Santa Barbara, California, June 15–20, 1953, under the sponsorship of the California Conservation Council, Montecito School for Girls, Santa Barbara Botanic Garden, Santa Barbara Chamber of Commerce and Convention Bureau, Santa Barbara Museum of Natural History, Santa Barbara College of the University of California, and Westmont College. A well organized committee made up of representatives of these institutions functioned effectively under the chairmanship of John E. Cushing.

Registration headquarters were in the auditorium of the Civic Recreation Center, which was large enough to afford space for exhibits of scientific books and instruments, as well as special exhibits provided by the Botanic Garden, Conservation Council, Natural History Museum, and others. Immediately adjacent, Baylor Lounge of the Recreation Center was available for informal meeting and conversation.

Scientific sessions were held at the Recreation Center, in near-by hotels and theatres, in the Carillo Auditorium, at the Museum of Natural History, and at the Art Museum.

General sessions included an afternoon tour and social hour at the Santa Barbara Botanic Garden on the opening day of the meeting, a general reception the following afternoon sponsored by the California Conservation Council and cooperating organizations, and two evening addresses. The first evening lecture was the presidential address of C. D. Shane, Director of the Lick Observatory and President of the Pacific Division, AAAS, who spoke on "The Distribution of Galaxies in Space." The following evening W. F. Libby of the Institute for Nuclear Physics, University of Chicago, spoke on "Radiocarbon Dating." Each of these addresses drew a large and attentive audience.

Meetings of the Pacific Division differ from national meetings of the AAAS in that no sectional meetings are held as such; the scientific sessions are organized entirely by the affiliated and associated societies. Twenty organizations participated in the Santa Barbara meeting, as follows: American Meteorological Society (123rd National Meeting), American Nature Study Society (Western Division), American Phytopathological Society (Pacific Division), American Society for Horticultural Science (Western Section), American Society of Ichthyologists and Herpetologists (Western Division), American Society of Limnology and Oceanography (Pacific Section), American Society of Plant Physiologists (Western Section), Association of Pacific Coast Geographers, Astronomical Society of the Pacific, Botanical Society of America (Pacific Section), Cooper Ornithological Society, Ecological Society of America (Western Section), Herpetologists League, Nature Conservancy, Pacific Science Board, Society of American Bacteriologists (Southern California Branch), Society for Experimental Biology and Medicine (Southern California Section), Society for Systematic Zoology (Pacific Section), Western Society of Naturalists, and Western Society of Soil Science. Some 400 papers appeared on the programs of these societies.

At the meeting of the Council on Wednesday afternoon, Edwin R. Guthrie of the University of Washington was elected President-Elect of the Pacific Division. The President of the Division for the coming year is A. H. Sturtevant of the California Institute of Technology. C. D. Shane, the Retiring President, becomes Chairman of the Executive Committee.

Ralph Emerson of the Universiy of California at Berkeley, and Moyer D. Thomas of the American Smelting and Refining Company, Salt Lake City, were elected members of the Executive Committee. Richard Van Cleve of the University of Washington and Jerzy Neyman of the University of California at Berkeley were elected to membership-at-large on the Council.

Action was taken to amend the constitution of the Pacific Division to include "that portion of Montana west of the Continental Divide" in the territory of the Division. This action was taken on the basis of a poll of the Montana membership by the Administrative Secretary of the AAAS, and was approved by the national Board of Directors.

Action was also taken to invite the National Science Teachers Association and the American Association of Physics Teachers to become affiliated societies of the Pacific Division.

The next meeting of the Pacific Division will be held at the State College of Washington in June, 1954, the exact dates to be decided by the Executive Committee at its October meeting. It was decided in response to invitations pending to hold subsequent meetings as follows: June, 1955, California Institute of Technology, Pasadena; June, 1956, University of California at Davis; and June, 1957, University of Washington, Seattle.

Raymond L. Taylor and John A. Behnke of the Administrative Staff of the Washington office spoke briefly of the forthcoming national meeting of the AAAS in Berkeley in December, 1954, and related matters. While desiring the widest possible participation in the Berkeley meeting, they urged that societies associated with the Pacific Division hold their June meetings as usual. Such procedure is encouraged by the fact that meetings of the Pacific Division scheduled for June, 1954 and June, 1955 are at considerable distances from the San Francisco Bay Area, so that a national meeting on the Pacific Coast should not affect the usual regional activities.

TABLE 1

GEOGRAPHICAL DISTRIBUTION OF REGISTRANTS*

Arizona	28	New Jersey	1
California	**766**	New Mexico	5
Colorado	4	New York	7
District of Columbia	5	**Nevada**	**6**
Florida	1	Ohio	4
Idaho	**4**	**Oregon**	**50**
Illinois	5	Texas	3
Maryland	3	**Utah**	**32**
Massachusetts	5	Virginia	1
Minnesota	1	**Washington**	**48**
Missouri	3	Wisconsin	1
Montana	**2**	Wyoming	2
Total, continental United States			987
British Columbia	**19**	Japan	2
Hawaii	**9**	Norway	1
India	2	Pakistan	1
Italy	1		
Total, foreign or overseas			35
Grand Total			1022

* Boldface type indicates the seven states, the territory of Hawaii, and the Canadian province of British Columbia that comprise the Pacific Division of the AAAS. Their combined registration was 936 or 92% of the total.

In addition to the luncheons, dinners, and breakfasts held by various societies, there was a well-attended Association Dinner, and a highly successful outdoor barbecue held on the new campus of Santa Barbara College of the University of California.

The total registered attendance at the meeting was 1022 drawn from a wide geographical area, as shown in Table 1. Although predominantly a divisional meeting, all sections of the United States were represented, and there was a gratifying attendance from British Columbia and Hawaii. There were registrants, principally exchange professors and students in American universities, from five foreign countries.

Despite final examinations and the beginning of summer schools, which prevented some teachers from attending, nearly every center of learning in the region was represented. There were registrants from 122 communities in California: *e.g.*, Los Angeles, 144; Berkeley, 80; Santa Barbara, 73; Pasadena, 45; Riverside, 44; Davis, 43; Palo Alto-Stanford, 22; San Francisco, 22; San Diego, 18; Santa Monica, 15; and La Jolla and Sacramento, 14 each.

ROBERT C. MILLER

Pacific Division Secretary, AAAS

MONTANA AND WYOMING JOIN THE WESTERN DIVISIONS

As a result of requests from members in the states of Montana and Wyoming, the question of the incorporation of these states in the Southwestern and Pacific Divisions of the Association was given careful study by the administrative office. A poll of the members was taken to determine their preferences. Of the 76 replies received, 69 favored affiliation with one of the Divisions. Wyoming voted 24 to 1 for the Southwestern Division. The Montana vote was a tie with a majority in the eastern part of the state favoring the Southwestern Division and a majority of those in the west expressing a preference for the Pacific Division.

The Executive Committee of the AAAS at its meeting December 26–29, 1952, authorized the administrative officers to work out an acceptable distribution of Montana between the Divisions and approved the incorporation of Wyoming into the Southwestern Division. By action of the Executive Committees and Councils of the two Divisions (the Southwestern Division at Tempe, Arizona, April 22, 1953, and the Pacific Division at Santa Barbara, California, June 19, 1953) Wyoming and Montana east of the Continental Divide were made a part of the Southwestern Division and Montana west of the Divide was formally accepted as part of the Pacific Division.

Bozeman, Billings, Great Falls, and Helena are the major Montana membership centers which now become part of the Southwestern Division. Missoula, Hamilton, and Butte are now in the territory of the Pacific Division.

CORRECTION

In the article "The Boston Meetings of the Association: A Bit of Background," (THE SCIENTIFIC MONTHLY, **77,** 118) it was stated that of the 15 past presidents of the Association now living five are residents of New England. It should have been *six*: The name of Albert F. Blakeslee, for the past ten years Visiting Professor of Botany and Director of the Smith College Genetics Experiment Station, Northampton, Massachusetts, instead of being listed in a footnote, should have been included with Karl T. Compton, James B. Conant, Harlow Shapley, Edmund W. Sinnott, and Kirtley F. Mather. Apologies are offered to all concerned. *R. L. T.*